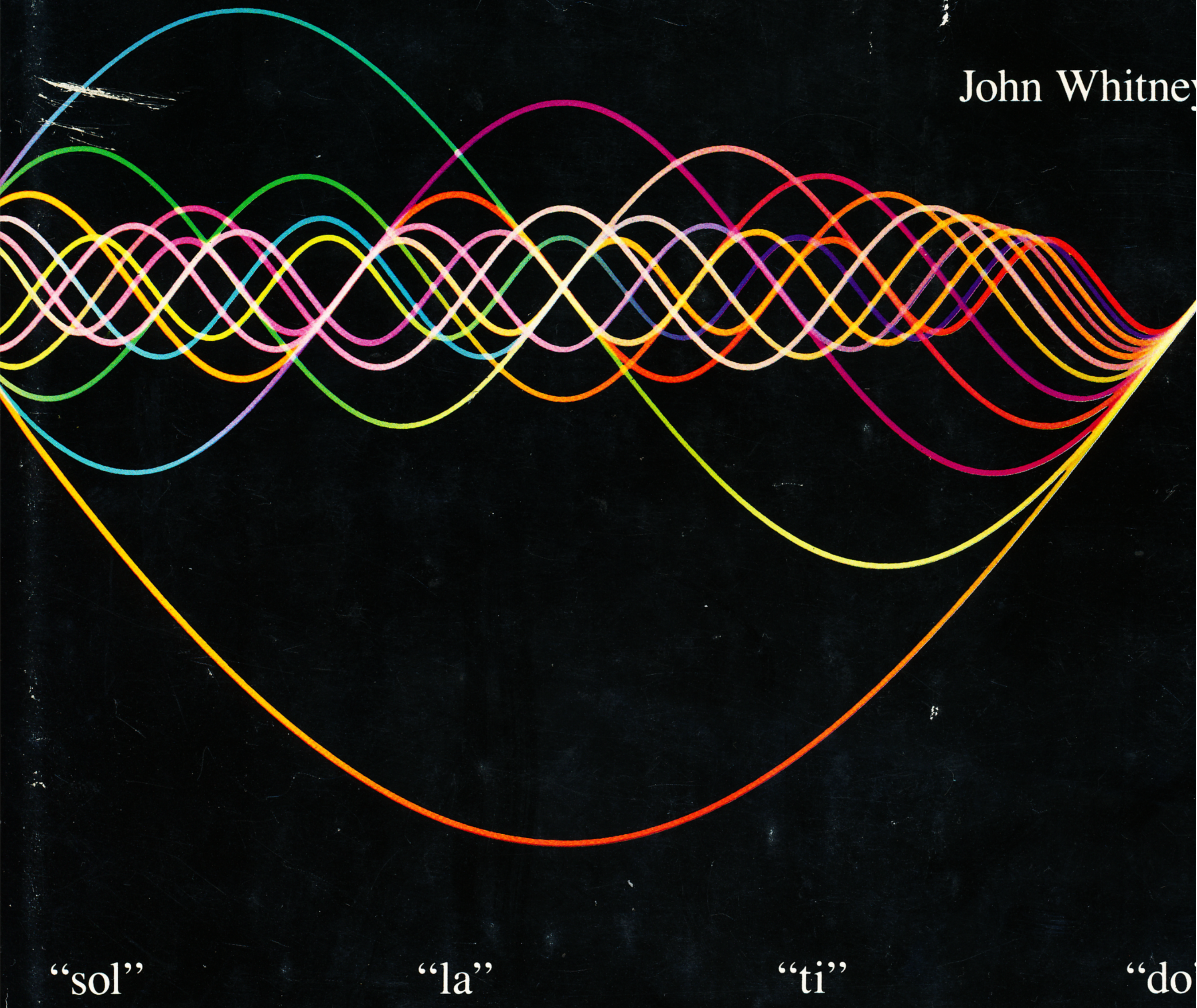
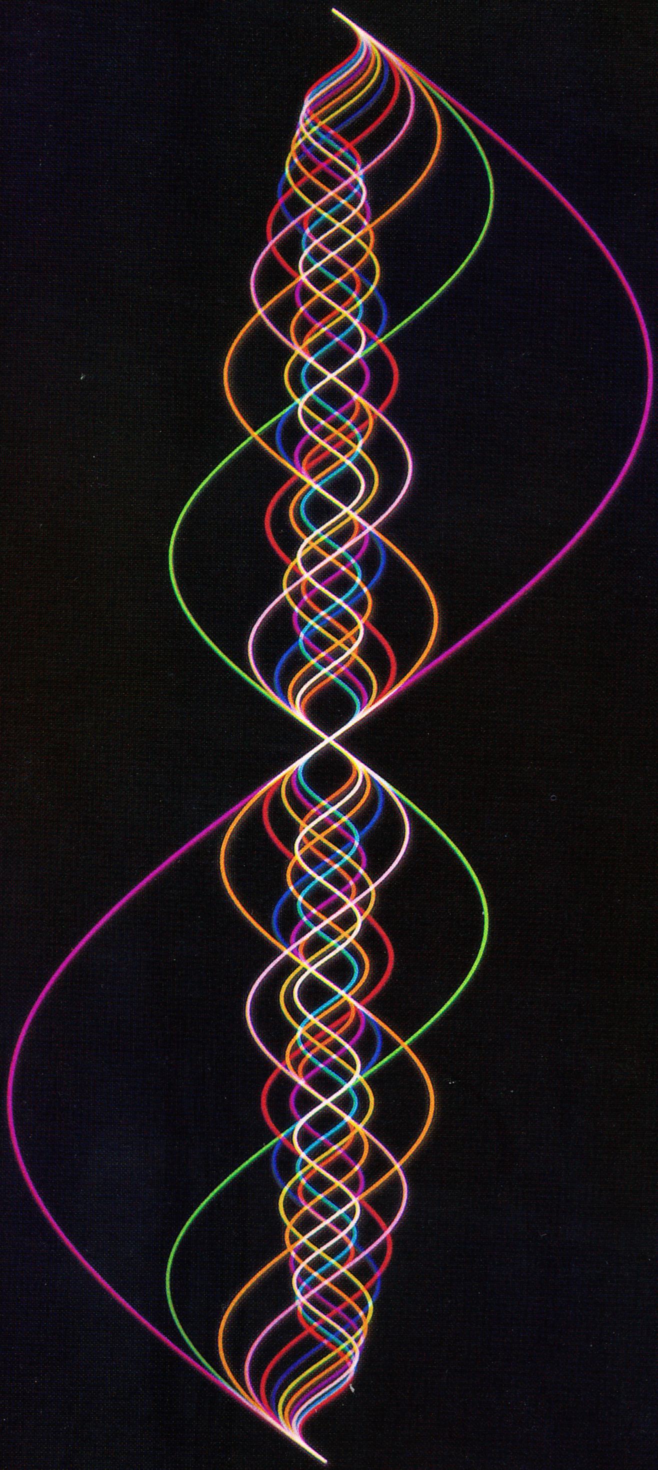
Digital Harmony

On the Complementarity of Music and Visual Art

John Whitney





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Dedication

When I first went to Paris, I did so instead of returning to Pomona College for my Junior year. Looking around, it was Gothic architecture that impressed me most. And of that architecture I preferred the flamboyant style of the fifteenth century. In this style my interest was attracted by balustrades. These I studied for six weeks in the Bibliotheque Mazarin, getting to the library when the doors were opened and not leaving until they were closed. Professor Pijoan, whom I had known at Pomona, arrived in Paris and asked me what I was doing. (We were standing in one of the railway stations there.) I told him. He gave me literally a swift kick in the pants and then said, "Go tomorrow to Goldfinger. I'll arrange for you to work with him. He's a modern architect." After a month of working with Goldfinger, measuring the dimensions of rooms which he was to modernize, answering the telephone, and drawing Greek columns, I overheard Goldfinger saying, "To be an architect, one must devote one's life solely to architecture." I then left him, for, as I explained, there were other things that interested me, music and painting for instance. Five years later, when Schoenberg asked me whether I would devote my life to music, I said, "Of course." After I had been studying with him for two years, Schoenberg said, "In order to write music, you must have a feeling for harmony." I then explained to him that I had no feeling for harmony. He then said that I would always encounter an obstacle, that it would be as though I came to a wall through which I could not pass. I said, "In that case I will devote my life to beating my head against that wall."

John Cage–A Year From Monday

When I first went to Paris, I did so instead of returning to Pomona College for my Junior year. Looking around, it was Gothic architecture that impressed me most. And of that architecture I preferred the modest style of the eleventh-century. And in this style it was Chartres, the Royal Portal where I sat on the steps reading Henry Adams. Professor Kendall who conducted singing sessions at the Pasadena YMCA when I was in Junior High School appeared on the seat in front of me on my train to Italy. He was by then a Professor of Music at USC on sabbatical in Europe and touring Italy. I saw him again and again on this tour, and observed that he had no taste for the paintings of Giotto. My best friend in Paris, a native, claimed to be the principal Schoenberg authority in France whether he was or not. Certainly he was the only one teaching twelve-tone music composition in Paris in 1939 and I was briefly and informally one of his pupils. Two years later I explained to Arnold Schoenberg at UCLA that my friend, who was Jewish and who still lived in Paris, needed help to get out of Europe. But already Paris was an occupied city. No one could be helped who lived there. I too had a mind that harmony was a mere appendage to the body of music though my feelings for Beethoven and Schoenberg Quartets should have discredited that idea. It was not until many years later that I learned how important Pythagoras was to Islamic ideas of design. And later still when I learned how to deal with Pythagorean principles of harmony on the computer in a visual way. Now I apply the principles of digital harmony to both image and music. Now I **understand** what Arnold Schoenberg said to John Cage.

John Whitney–Pacific Palisades–March 1979

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Foreword

This book records the exploration of a single hypothesis, and reveals some modest triumphs as well as a curious problem which remains unresolved. Had this story begun in 1838 instead of 1938, there would have been nothing provisional or problematical in a young person's decision to make his way somewhere in the field of the arts or music as I have done. This century's destabilizing impact upon the arts from the Dadaist movement in the first or second decade to the present also rattles individual careers. Although it may be curious that my work, at its apex, appears to be both hypothetical and revolutionary, widespread late-century equivocations and tentative new directions unsettle the arts generally, and this history reflects that influence.

Richard Wagner's revolutionary career – personally, musically and technically – reveals little that was hypothetical or conditional about his life or his ideas. Even though he strained the conventions of harmony, the conventions themselves remained secure; there was no question about their validity. They were founded upon **the harmony,** the established laws of Pythagoras, that bulwark of music which Pythagoras had hypothesized and proved centuries before Wagner's assaults.

While not meaning to compare myself with that nineteenth century titan (1813–1883), I wish merely to contrast the two ages. Consider the following:

The late Harold Rosenberg referred to "... the profound crisis that has overtaken the arts in our epoch. Painting, sculpture, drama, music have been undergoing a process of de-definition. The nature of art has become uncertain. At least, it is ambiguous. No one can say with assurance

what a work of art is – or, more important, what is not a work of art."*

Indeed, "The nature of art has become uncertain," and for one sizeable block of composers, that grand Pythagorian certainty – **the harmony** – has come apart. Even so, the foundation of my work rests first upon laws of harmony, then in turn, upon proof that **the harmony** is matched, part for part, in a world of visual design. This is my hypothesis. This book, a record of the formulation of that hypothesis, will show how it has evolved as the basis for a life work. If hypotheses are rare in art, proof within a lifetime is rarer still. Proof in these times, Harold Rosenberg and many others would observe, is hardly likely, and there resides my curious problem.

This hypothesis assumes the existence of a new foundation for a new art. It assumes a broader context in which Pythagorean laws of harmony operate. These laws operate in a graphic context parallel to the established context of music. In other words, the hypothesis assumes that the attractive and repulsive forces of harmony's consonant/dissonant patterns function outside the dominion of music. Attractions and repulsions abound in visual structures as they become patterned motion. This singular fact becomes a basis for *visual harmony* with a potential as broad as the historic principles of musical harmony.

Stravinsky is known to have remarked, "Harmony is dead." He meant what I imagine Arnold Schoenberg might have observed before him, that late nineteenth-century practice of harmony was indeed moribund. Even so, the physical fact of the low-order ratios of pitch relations (octave, fifth, fourth, and thirds) is simply Pythagorean physical fact, and as real as pigment and canvas are to the painter. (My use of the term "harmony" throughout this book refers to that physical fact of orderly ratio in both its horizontal and vertical [linear and simultaneous] meaning.)

This book documents how the application of graphic harmony, in that "real" sense of ratio, interference and resonance, produces the same effect that these physical facts of harmonic force have upon musical structures. The book points to these forces of *visual harmony* at work in a number of my recent films.

***The De-Definition of Art* (New York, 1972), p. 12.

There remains a need for confirming demonstrations of that hypothesis in a larger body of work. Art, unlike science, is proved by art alone, not by mock-scientific experiment in the isolated case. Meanwhile, more exploration of the hypothesis continues by the only means available to the artist in this medium – by more work on film, tape or videodisc.

This book proposes to share the process of confirmation, study and productivity with others. The dimensions of this hypothesis, expanded in the decade since its conception, grew beyond the limits of my individual study. I would hope that others will find on these pages adequate primary lessons in digital harmony to begin explorations for themselves. Chapter XII includes listings and descriptions of three simple programs intended to provide the essential primary principles with which anyone may begin.*

Secondarily, this book demonstrates an example of technology's impact upon a career. Again, compare the ages. Wagner was not obliged to invent the symphony orchestra. The instrumentation needed to accomplish his revolution was simply amply available.

By contrast, a twentieth-century invention favored by some artists – the movie camera – has undergone many refinements requiring a constant reinvention of technique. This expensive instrument, and its associated lab processes, may be obsolete before the next century. Indeed, as indicated in the second section of this foreword, motion picture technology has been practically eliminated from my current artworks – its place in production is being taken over by computer-related and video processes.

Computer technology has been available to a few artists for less than two decades. At the same time that computers are becoming household utensils, a mixture of high expectation and stubborn opposition surrounds the tentative use of these instruments for art. About the computer's applicability in art there will be much more to say throughout the book.

The purpose of this book, then, is to define, as much as I understand them, the principles of harmony as they apply to graphic manipulation of dynamic motion-pattern by computer. Whether my efforts constitute a final valid grammar is irrelevant. The purpose is to document my own

*A workbook is in planning stages as I write this.

approach and to propose the seminal idea of making **an** approach. I suggest there may be more than one approach needed to establish this lively new visual art. In the chapters to follow, I will attempt to describe an art that is to be seen **and** heard, diverse in its potentials both for narrowcast (fine art) and broadcast (popular art). I expect to see an art that will show well on the video screen and in a new kind of theatre and gallery; it will be played everywhere on videodisc.

Words On My Hardware and Processes

Small computers have sufficient graphic capability for what I will be discussing here. Mine is an Andromeda Systems LSI-11, a 16-bit machine that operates on programs in Pascal similar to those discussed and listed in Chapter XII. The overall procedure is to generate graphic action sequences to be recorded one frame at a time with a camera of some sort (video, 8, 16 or 35mm movie camera). My graphic display terminal is a Tektronix 4002 (an old model, but one which I found to be well designed for my use).

At present I am in the process of installing a complete digital music composing capability. As I will explain in detail on these pages, image and sound must ultimately be composed hand in hand by techniques that were unavailable before. Of course, faster equipment would be useful for instant real-time playback of image with sound.

Already there exist numerous personal computers that provide an approximation of sufficient programming power, including musical and graphic capability, to generate design such as I will describe in this book. Small computers are available that have one-frame-at-a-time capability, at non-real-time frame generation speeds. Only a few weeks after I spoke at the First West Coast Computer Faire in 1977, a very young man showed me his working example of the basic action design of my film *Arabesque* which I had projected and analyzed. He worked out the action pattern so as to run slowly, in real-time, on his Apple Computer.

My current procedure is to generate 2- to 10-second actions (or some longer than 1-minute sequences) which are filmed by a 35mm motion picture camera mounted above the Tektronix cathode beam display which is placed, face up, at the exact focal plane of the camera. The computer program sends a signal output that switches the camera for a one-frame-

at-a-time exposure after the CRT image has been computed and displayed. Sometimes the system is run day and night, without needing my attention, to complete a complex sequence that I have planned.

The film is developed in my own processor and then run on a film viewer, when, for the first time, I can judge if my planning was right and if the **action** quality conforms to my vision of its function, and whether I find in it some relevance to the larger scheme of a complete work.

In the past, making *Arabesque* for example, a "library" of these black and white action sequences was accumulated on film over a period of months; each action was selected by that slow process of judging, one at a time, many many trial sequences, and selecting only those which seem to fit my growing discernment of a broad "design" for a composition.

In the making of *Arabesque,* I edited and compiled the final film in color. At that time, editing was not a computer process but, more or less, a standard film editing routine involving an optical printer with color filters at the source of illumination. Any black-and-white film of a computer sequence can be copied onto color film in any color by use of my optical printer. Now, however, and more so in the future, the techniques will translate into operations with digital computers and video editing practice. Direct, interactive color control, the repertoire of video synthesis of texture and feed-back type image enhancement will colorize and "orchestrate" my basic computer-generated action compositions.

Words of Thanks

Many persons assisted me in the preparation of this book. First I wish to name a few of the several people from computer science fields who repeatedly displayed patience and genuine interest throughout the past fifteen years and so aided my progress enormously.

Dr. Jack Citron of IBM, Fredrick B. Thompson, Ph.D., at CalTech and Dean Anshultz, Ph.D., at Information International Inc.; all possessed a broad understanding of my needs for computational particularities and supplied them generously.

With Larry Cuba, the pattern changed: a new generation and a new, specialized interest has surfaced. The change with him is his clear intent to specialize as an artist in this field. He assisted in the making of

Arabesque and shares with me many of the problems of design and programming which need continuing study.

Paul Rother came to my studio with similar ideas of reciprocating, and he stayed to do all the Pascal programming I presently use. Without his help, the listings of Pascal programs in Chapter XII would not be so concise and organized.

Of this generation, now there are more. Scott Kim, Paul Newell, Jack Bowman, Augustine Lai, David Butterfield, Richard Moszkowski and others, each has made a contribution. The list is incomplete; still I wish to thank each one.

My wife Jackie has given much assistance, and her insight was an asset on a broad range of matters pertaining to this book. Before our marriage she was an independent painter – exhibiting (and selling) with a free and lively sense of direction; then, throughout my years of film making, her extraordinary intuitional and critical sense was always present. She participated in some of the most spontaneously creative moments of my film work. And still, meaningful to our married lives, her attention and love within our five-fold family is crucial.

We have three mature sons, involved with film more and less. I was blessed by their triadic diversity which continues to bestow benefits by their criticism and assistance with this book. Their names are John, Michael and Mark (apostolicism neither intended nor offered).

Then there is my brother, James Whitney, whose career is as long lasting as Jackie's and mine, and serenely consistent. The diversity of our personal dispositions pointed us in different directions early. I admired and envied his patience, discipline and craftmanship. Curiously, a powerful motive to probe deeper into the maelstrom of electro-optical machine technology – largely my way with machines – was ostensibly to match what he made by hand.

At one point we spent months building an optical machine. The machine was for his use, made by his labor; I only advised him. He made one extraordinary film with that machine.* I was away. When I returned, he had removed it all from his studio – "to preserve his sanity," he said. For a few years, he abstained from filmmaking altogether; instead

*See James Whitney's film *Lapis*, and all his recent films.

he perfected a skill at producing Raku pottery, a natural antidote. His current film work is distinctive for its maturity and his philosophical mastery of his own personal form.

It is my brother I thank, along with Jackie. Each has helped me to maintain a measure of balance, within the easily exceeded limits of technological applications in the arts.

My friend, Pearce Young, former Judge of the Superior Court of Los Angeles, Rhodes Scholar and former member of the California State Legislature, proved to be exactly the willing expert this first book needed. In truth, his help was obviously more valuable for his lively interests which relate to his pioneering encouragement of home computing through his contributions to the founding of the Southern California Computing Society and his many present interests in the development of computer-aided educational programs.

William Moritz, Ph.D., critic, film maker, poet, and deeply involved student of the avant gardes of film, accepted my request for help in balancing my perspective on the filmmaking of my contemporaries, some of whom approach design problems similar to those I have studied. Not having used a word processor, he was amused with mine and it developed that he sat at the terminal working closely with me for many productive sessions, bringing this book into much better shape than it once had. If filmmakers are critical of my ideas regarding aspects of their medium today, they should turn their attention towards me, not the good doctor Moritz. For I argued with him and, of course, prevailed, it being my book. But I owe William Moritz much gratitude for his help and for editing the appendix and creating the index.

Lawrence Morton provided advice on the subject of music. I needed to be reminded that I am neither authoritative nor professional in matters of music. Lawrence Morton is professional. He is one of the most dearly admired men of music on the western side of the United States having been involved in creating highly respected contemporary chamber music concert programming in Los Angeles and Ojai throughout the second half of this century. He applied his thoughtful attention to musical detail and has contributed much to the book. However I could not begin to satisfy his rigorous requirements for the language of music; I needed to stretch conventional meaning again and again. He is blameless for this.

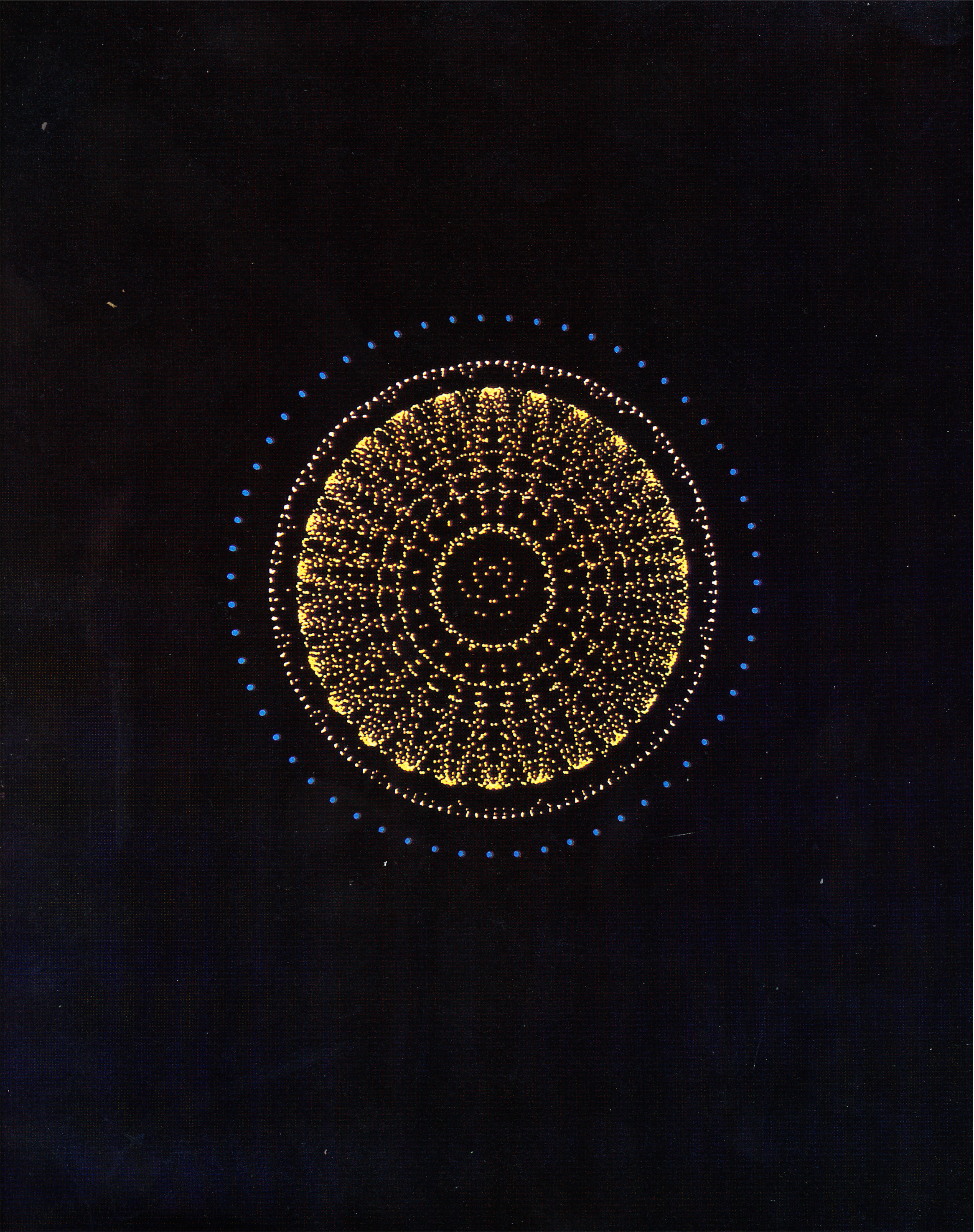
I may, or may not, have gained anything by my literary innovation.

Finally I needed assistance from someone who would know what I did not know about contemporary art and American artists throughout the period of my own struggles, as Brian said, "at the barricades of an art frontier." Brian O'Doherty's role as an editor of *Art in America* and his present position with the *National Endowment for the Arts* certainly overqualified him, while it honored me to receive his help.

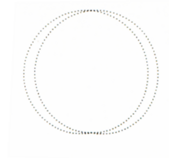
This book is designed by Ron Rozzelle. We have a bond of understanding about design problems; we were both associated with the office of Charles and Ray Eames, though at separate times. Most who knew and worked in and out of the Eames design office over the past thirty years have come away with a bond of some sort. Work there was almost always a difficulty bearing with it a genuine sense of accomplishment which we always shared finally at the grandest conclusions. I know we will share that sense of accomplishment when this book goes to press. Ron is tireless.

My deepest gratitude and sincere thanks go to Ed Kelly, Nicholas Bedworth, Sheila Hayward and Ellen Klempner of Byte Books for their consistent help and cooperation in the making of this book.

Pacific Palisades, July 1980.



Chapter I



On With The Revolution

Another major media revolution, ranking with sound for the movies, radio, or the upheavals of TV, will soon introduce wonderful inventions into the home. The videodisc, a new product in the marketplace, will generate the greatest potential for change usually associated with this kind of turnover. The videodisc's ingenious application of digital reproducing technology combines microscopic sight and sound tracks of great technical efficiency and economy.

Being an early partisan, I trained with computers for years, underground, preparing for the day when videodiscs would take over the marketplace. I dreamed in "video music" and plotted secret revolutionary fusions and transfusions of the arts. More on this will be discussed later.

As is usual in the tumult of revolutions, a promising application for the videodisc's sight-and-sound intermix languishes more in confusion than in hope. Yet an inevitable artistic application, which I will describe, should popularize an exciting and innovative fusion of music and visual art. The future of an integral aural/visual art is assured by wide distribution through the videodisc's economics and logistics. What would an integral aural/visual art be like? And what's new about it?

Al Jolson's voice and his picture on the screen were about the only aural/visual components of the "art" of the first sound movie. Between that day and now, much has happened in the worlds of art. Both the fine arts and the popular arts have been changed by de-definition and even ephemeralization. Cross-fertilization and synthesis opened many eyes and ears to new and different points of view regarding art and music. So it is timely to compare the perception of music with the viewing of art.

See p. 132 for a description of these chapter heads.

Most people visualize music as two-dimensional, with time represented by the horizontal lines and pitch by vertically arrayed symbols, as is the convention on paper. But the perception of music is not two dimensional. The ears reside at the center of a spherical domain. We hear from all around. We hear music as patterns of ups and downs, to and fro in a distinctly three-dimensional architectonic space – a space within.

The eye, more outwardly oriented, perceives objects and events outside at the point where our eyes focus. Yet the eye enjoys design equally as well as the ear. The mind's eye shares with the ear any inward experience of architectonic spatial constructions and would perceive them with the same pleasure, were they to exist.

The fact is, however, that these interior fluid visual edifices hardly exist. Anyone can visualize an architectural fantasy of music dancing in the head, but manifesting it in reality is another matter! Each century since Leonardo, a vision, grand and obscure as its myth, compelled one or two inventors to struggle with the pathetic inadequacies of the color organ. Twentieth-century abstract art has been a training ground for visual response to musical experience, but in the mind's eye, architecture **in motion** lies at the root of our enjoyment of music. Many people, with closed eyes at a concert, are "watching" the music, but after all these centuries, there still exists no universally acceptable visual equivalent to music! It should exist, and it will soon. Incidentally, it will surely not be called "video music."

Many people whose innermost responses, in fact, fit the above description, are nevertheless apprehensive about the idea of abstract musical architectonics; they imagine music to be exclusively representational. Some visualize those descriptive images called upon by the romantic composers of tone poems, while others falter with literal "realities" by associating music with images of conductor, performer, opera star, rock star – even the occasionally lurid images of pop music lyrics.

Besides the technicalities, then, this is another reason why there exists no universally acceptable visual equivalent to music. Also we may observe that many more people consider music a totality by itself. Music does not **need** images any more than paintings **need** sound. (Of course, this does not invalidate the hypothesis presented here.)

The exact perceptual experience of music needs a more precise term

than the lame metaphor "architecture." There are no words for the dynamics of architectonic pattern which stress the fluidity and diverse expressiveness of musical motion. The ear perceives patterns of tone by means of infinitesimal inflections of microscopic bundles of air: the tonal "clay" the composer sculpts is flexible and dynamic. Newton's laws of mass or thermodynamic laws do not cease when a string quartet performs. Air moves more swiftly, and easier than clay or paint. Almost any material an artist might select is too sluggish to sculpt in time and motion – too languid or too inertial for a visual medium meaning to imitate music, or to vie with music's dynamism.*

In the last third of this century, we acquired a visual medium which is more malleable and swifter than musical airwaves. That medium is light itself. While it was always available, the means to modulate light precisely and faster than sound (on a cathode-ray computer display, for example) is a very recent practicality. Musical instruments that modulate the air medium of hearing are now matched by other instruments which modulate, with greater exactitude and speed, the light medium of sight.

These two will make a surprisingly happy combination, provided the influences of musical tradition do not dominate or dampen the potential vitality of the visual sibling. The audio-visual tracks of the videodisc obviously are best suited for this balanced complementary partnership of sound and sight.

In the sense that the natural laws of acoustical physics must have accompanied the evolution of atmosphere on earth, laws of harmony must have accompanied the very evolution of human musical culture, long before Pythagoras. But in spite of the extraordinary successes of the classic composers, and in spite of the facts of harmonic law, many composers of this century have rejected principles of harmonic relationships and tonality. The "crisis" of contemporary music noted by Pierre Boulez and others is due largely to this rather unpopular ongoing search for other principles with which to capture a world of "new musical resources."

Yet the art of music deals with harmonic laws of physics. The basic intervalic ratios of tuning and tone sequence exist simply as physical

*See Frank J. Malina, *Kinetic Art* (New York, 1974); Frank Popper, *Origins and Development of Kinetic Art* (New York, 1968); and George Rickey, *Constructivism* (New York, 1967).

fact. Arnold Schoenberg told John Cage, "In order to write music, you must have a feeling for harmony."* The truth of this remark was not diminished by Cage's protest that he had no such feeling for harmony – just as the truth of physical law would not diminish were the late sculptor David Smith to have protested that he had no feel for the weight and mass of steel.

Music doesn't just pass time. Music shapes time. In the symphonies of Haydn and Mozart, repeating elements occur twenty to forty times. This amount of repetition (within a rhythmic pattern) seldom occurs in poetry, or prose or any of the other arts that evolve in time, except music. It is as if the composer states a figure, takes thirty or forty steps (beats of a driving rhythm), and follows that with another figure. The steps are hardly repeats. Steps along a flow of time take us from here to there in time just as surely as our footsteps transport us in space. Steps give shape to time, and they pace out the dimension of time, in that sense. Only harmonic order allows this. Even the **tone** of a drum shapes time.°

A crucial force of music – the harmonic interplay of tonal cohesion and gravity – punctuates time with resolution and with metric and rhythmic order. A crucial fact of musical art – the harmonic force (chordal or melodic) – works its way upon the sense of hearing whether or not the composer elects to shape this force for our ears or whether he remains a naïve foil to its unbridled power.

Briefly, the acquisition (intuitive and conscious) of harmonic principles began the art of building with time as surely as civil engineering (also both intuitive and conscious) began the art of building with stone. Now we can "build" aural and visual compositions for videodisc.

Today we apply harmonic laws to build visual structures. New instruments modulate light more accurately and swiftly than musical instruments modulate air. Considering time-structured arts of the future, we can create integral aural/visual compositions in a domain of harmonic continuity. A universally acceptable visual art – an equal partner to music – is arriving hand in hand with current computer music developments.

With these twin developments there follows a change in prospects

*See Dedication, p. 1.

°Victor Zuckerkandl, *Sound and Symbol* (New York, 1956), pp. 212–223.

for music. Within this decade we will see that participants in search of "new musical resources" produced unexpected results. A major task assumed by a few composers at the opening of this century, beginning as a search for new musical resources beyond classical harmony, ends in a full-scale reevaluation of architectonic temporality of which – I submit – the history of music is only the first chapter.

If, as is often charged against "modern music," the wellsprings of harmonic vitality ran dry about a decade or two into this century, then perhaps all is about to flow once again, but now with complementary aural and optical resources. The imaginations of many composers including Scriabin, and painters, including Kandinsky, symbolize the ongoing search, over many generations and with inadequate technology, to discover *complementarity* for eye and ear. Both Constructivism in art, seeking a rapport with music, and modern trends in music, probing for a way beyond its traditions by any and all means, will realize a kind of consummation through this complementarity.

A composer may look forward to executing with his own hands an aural/visual creation. Using a new kind of versatile instrumentation and compositional procedures, borrowing from computer programming and editing practice, this new composer will enjoy the practicality of hands-on execution of his own work.

In contrast to visual artists, immediate, direct intuitive contact with his work was always the composer's dilemma. Between composer and his music "lurks" portentously – in triumph or for disaster – his interpreter, soloist or ensemble. But now, digital instrumentation (the next phase of computer technology in the arts) provides the capability to modify, over and over, and reshape a composition without signal degeneration. In effect, a composer becomes the performer of his own creation for better or for worse; this responsibility was traditionally assumed by both the painter and sculptor without question.

When the instruments are available, composers will find a visual medium hand in hand with the musical medium, both with the same editing and viewing and reedit capabilities. This intimate sensuous contact with his work creates a new role for composer-performer in a way unprecedented in five hundred years of musical instrument refinement.

Composers will discover a congruence of aural-visual partnership as productive as that which they found for centuries in writing for combinations of all kinds – keyboard, skin, string or wind. That partnership will be grounded on valid harmonic interrelationships equally applicable to sound and image. The creative product of these new composers will go directly to the videodisc publisher.

I started this chapter with reference to myself, a media "revolutionary," training underground for the day which is dawning even as I write this book. It has been a long time coming. Early in the fifties, I believed that this wondrous day had come – or would come next month, or next year. In truth more than forty years have passed since the beginning of my story. In the next chapter I shall begin at the beginning.

Chapter II

Beginning

The geometry of iron rivets in iron plates painted white, the lines at the edge of a plate, and the rolling, shifting shadow cast by all of these, especially at the curve of a plate – I tried to film these fragments that I saw in a cine camera viewfinder aboard a Rotterdam-bound freighter during the summer of 1938. Fernand Léger or an artist at the Bauhaus might have painted such geometry as I saw it through the eyepiece. But my ideas were not like theirs – I didn't know about them. I was trying to compose music, not painting. I knew little about living painters, abstract art, Arnold Schoenberg or what I was going to do with myself. Much music had touched me, I knew that. And at my age, it seemed "schizoid" to love music plus cameras and telescopes, but I did (I had ground a mirror and built a telescope a few years earlier). I was frustrated with college, so here I was, halfway to Europe where surely, I thought, I'd find some sort of a worthwhile career and get started with my life.

The wonder is that I did "get started." A year or two later I wrote a friend that I had chosen art "and the lean way of life." Born in California, of parents fresh from the Midwest, I had never known anyone who made money painting or writing poetry or music. Neither had Jackson Pollock nor Mark Rothko, nor would they for many years to come. Yet in fact I knew better than hundreds and hundreds of my contemporaries that I wouldn't make money with art. I knew I was beginning a career in a kind of filmmaking that hadn't been invented. Erroneously, I thought I had invented the very idea of an abstract cinema art that would **look** the way music sounded.

With viewfinder focused on the white iron shipboard structure, I had

thought to direct my camera by twisting and turning, and to "cut" from one take to another in rhythmic ways. I had no story to tell. This was composing "music" out of the motion of the camera. I had no intention to bring back home movies of this trip to Rotterdam. The trip was not a summer excursion; I had convinced my father it was a matter of some serious business having to do with my education and future. As it turned out, that film was unrhythmic and depressingly unmusical for a first effort designed to begin my search for a new art that would look the way music sounds.

The summer in Europe ended in Paris where I lived until the following summer. I attended two glorious performances of the entire set of Beethoven string quartets during which my mind dwelt upon figurations in space. I could agree with music critics of Europe's nineteenth-century flamboyant era, who wrote on and on about "liquid architecture." I visualized that. I began to be convinced that such liquidity could be visualized – on film now – with twentieth-century art and technology. What I needed was more filmmaking skill and a way to point my camera at something that would not be as hopelessly static as that freighter's iron plate. This prospect tended to temper and rejuvenate me, deflated as I was by the return from my single provocative year in Europe.

Alas, the whole world is a static place when you compare it with Beethoven quartets! Then I learned that I hadn't invented anything at all. Even Leonardo had sketched ideas of music and its likeness to colors. There had been more than one century of premature color-organ experimenters. Again I was disappointed. Worse yet, after returning home, I learned that European filmmakers before me had made films which they called symphonies, such as Walther Ruttmann's *Berlin, Symphony of a City.**

*It is not clear in my memory whether these "symphonic" efforts or those hand-drawn animations (meant to "illustrate" music) affected me most at this time. Between the mid-40s and the mid-50s, I read about (and no doubt I viewed examples of) most of the body of this "musical" work—films by Oskar Fischinger, Len Lye, Norman McLaren, Lotte Reiniger, Viking Eggeling, Hans Richter, Alexander Alexeieff, Mary Ellen Bute and Joris Ivens. All but Reiniger, Eggeling, Ruttmann and Ivens have since become personal acquaintances. Any one of them would, I believe, share with me the convictions expressed in this book, had they shared my experience with the late marvels of computer graphics. For further information on these animators, see Robert Russett and Cecile Starr, *Experimental Animation* (New York, 1976).

I would have given up had I not **known,** in my youthful way of dreaming as much as thinking, that they were all wrong. I wondered if anyone else realized why every attempt at visualizing music had fallen hopelessly short of being as dynamic as music. Pointing their cameras at the world, all those "symphonists" inadvertently recorded the stasis of the world, even as they filmed its busiest moments – its winds and storms and birds and water and city traffic. Those films are not symphonies, I thought, poetry perhaps, but not liquid architecture, not music. I was charged with new excitement. I never debated my ability to find my way beyond these transparent failures.

Those films were records of events on the surface of a gigantic body (Earth) whose mass and gravitation permeate everything with the immutable laws of motion. Not so with the motion of music. Its motions range from cosmic proportions to a tiny flutter in a medium of such fluidity that it seems to be unconstrained by inertia or gravity. I was convinced that the eye should see what the ear perceived in that aural cosmos. Obviously, I enjoyed the idea that I would find the way.

I had tried to transcend stasis by plying the stock-in-trade of the movie camera, holding it in my hand while utilizing its own mobility on shipboard. Yet the more the camera moved, the more the world's gratuitous motions, hither and yon, close up or distant, in front or behind, gave way to one common slur in one direction, flattened in another. The strongly spatial and multiplex polyphony of the real world gave way to flat blur. I did not like that – this was not as it should be. It was just not a symphony. The optical equal of that deeply spatial experience of music would have to be found elsewhere.

Found where? This question caused me to reflect upon the anatomy of musical "abstraction." There is no such thing as the harmonic organization of musical tone in nature. Occasionally a stone may ring like a bell, birds pattern "song," but there are few natural bells, fewer natural flues where the winds sound organ tones. Even the whistle of wind is eerie and non-musical. Patterning of musical tones is a man-made reality of the aural world, universally accepted as such, but nowhere looked upon as an abstraction that has been extracted (or abstracted) out of the natural environment, nowhere regarded as a manifestation of the environment.

Musical tones are a special creation. They are abstract only in the sense that they are the raw material of the liquid architectonic structure of music. On the other hand, wherever I pointed my camera, I failed to discover that special quality of any material possessing the controllable visual fluidity that I desired. No abstraction in my camera had the generative potential, the capability to propagate fluid patterns or especially, the liquid variability of the intervalic families of musical tones.

Quite the contrary: pointing my camera anywhere resulted in recording images of somewhere. If the camera's record is unclear, blurred by the smear of too fast panning or being out of focus, the sense of somewhere as place is simply flattened. The spatial content of an image is flattened. The eye resists this attempt to domesticate abstraction. This sort of deception hardly satisfies the eye, because the sense of being (or seeing) **somewhere** is so strong. The eye is the natural master of pattern recognition. The eye demands satisfaction by invoking in us strong feelings of puzzlement. Our very eyes themselves ask, "What is it?" They strain to restore a blur to what it was **supposed** to be. Eye and brain make these demands, even by inducing nausea in the viewer if his sense of optical upright equilibrium is deceived on the screen.

I concluded that the eye will not passively accept a filmmaker's strategy when he assumes that, by obscuring the presence of place in the world, and by some gestural motion with his camera, the viewer will be "transported," purposely, somewhere else, into a world of abstraction. I found that abstractions, so derived, possess no power to communicate anything except what I judged to be arbitrary formlessness even if that formlessness is shaped into some imposed pattern. I observed that "composing" camera motions in my shipboard film, for example, produced none of the potential of a generative grammar, as do musical tones. It was clear to me, tones possess remarkable generative potential, else their productive utility might have been exhausted in, say the eleventh-century. Tones are not shaped by the composer; he finds the shape in the tones and thereby discovers their generative potential.

Moreover music is not an abstracted picture of anything. When Debussy painted (or composed) *La Mer,* pictures of the sea had little to do with his flute and bassoon figurations. Still, these soft meditations are

evocative and just as lovely as the sea itself.* Why? Why do they move us as intensely as do childhood memories? And then, what of other feelings? What of the interior emotions evoked by the quartets of Beethoven? Overwhelming as they are, obviously these examples of "pure" music, these too, consist simply of figurations of tone and intensity. Yet how can musical patterns of an instrument or voice impact so profoundly upon one's feelings?

I became obsessed and charmed with such thoughts about the art of music – rhythm and harmony – and why just twelve tones were infinitely applicable. I began to explore ideas of creating structures of visual pattern. I commenced a search for the simplest building block, an alphabet, with which to construct an art of vision to match the art of music.

I was pleased to find that a hero discovered during my year in Europe should now provide the hint, or model, for the next chapter in my life. Arnold Schoenberg's principles of twelve-tone composition, while bearing only the most superficial similarities to my optical design problems, still influenced my film projects over the following years.

During my winter in Paris I had been instructed in some of the basic principles of Schoenberg's twelve-tone serial composing. Incompletely, I understood that a series or row of tones is constructed so that it can be transposed, retrogressed and inverted, forming an extensive array from which to draw all figurations of an entire composition. I did not understand that these techniques, more or less, were practiced by the Flemish polyphonists of the fifteenth- and sixteenth-centuries – and later by Bach.

My concept of the tone row, subjected to these transpositions, inversions and retrogressions, seemed readily adaptable to a film sequence. Figuratively, but not in fact, I could translate tone-row to filmstrip. I learned only very slowly and reluctantly that what I presumed to be the new musical art of "atonalism" meant not the abandonment of harmonic principles but their reassertion outside established conventions in new ways and with new force. My filmstrips displayed not the least suggestion of any effect parallel to the harmonic forces at work within the musical tone row.

*See Leonard Bernstein's analysis of Beethoven's *Pastoral Symphony* in *The Unanswered Question* (Cambridge, 1976), p. 153 ff.

Subtle intervalic interrelationships alter as the tone row is transposed up or down the twelve note positions just as in an earlier century a melody was altered by transposition into another key. They reform again by inversion or retrogression; all of this causes shifting and changing of the harmonic tensions and cohesions throughout. An image sequence seems to be well suited to the idea that it be inverted or mirrored. Any image, so treated, does suggest interesting symmetries. But it took a long while to comprehend that no visual action juxtaposed any way against itself, strung out sequentially as a (musical) variation upon itself, or cut into fragmentary figures for contrapuntal use – none of these had the impact that shifting harmonic forces do. In sum, no visual motion worked the way musical motion works.

It seemed I hadn't the slightest comprehension of the vast power of the workings of harmonic force in music. Why should I? I agreed with contemporary composer-friends (Cage and others) who discredited classical harmony and tonality with revolutionary zeal. Some of those even had a mind to "elevate" a protesting Arnold Schoenberg (grossly miscast) to the role of their vanguard leader. They were as misinformed as I of Schoenberg's true concepts but, by that time, I had begun to suspect that Cage and Schoenberg were as far apart as the earth and the most distant planet.

My best effort to apply Schoenberg's principles to film was not successful, not understood; nor was it ever properly analyzed. Instead, my attention passed from these inadequacies to a blanket rejection of prevailing ideas on the art of cinema. Film was not the technological art that would bring about a satisfying visualization of that liquid architecture as I had believed.

The movie camera was, after all, only a recording machine, good for documentation or drama. How could a reproducing instrument serve to contribute to a new visual art, any more than, say, a sound-recording machine might contribute to the art of music? (This was before the invention of the magnetic tape recorder which, for a short time, was indeed looked on as an instrument for composition.) Fortunately this sobering realization sent me searching ahead toward a single-handed effort to invent a machine that **would** be used as an instrument for composing

this liquid architecture.*

It was only after a decade of effort in another direction (with some compensating rewards along the way) that my tone-row/film-row experimental failures were clarified by a deeper understanding. More about this follows in Chapter III.

*See Appendix, p. 183.

Chapter III

Concept

My earliest joy with building things had grown from telescopes to cinema. But with my final disillusionment regarding cinema came a challenge to return to constructing a different kind of instrument for creating the visual fluidity which I foresaw. There followed about ten years of the most gratifying work. I patented an invention. I earned a reputation in professional motion picture circles as a pioneer in the development of slit-scan techniques and motion control systems. But in the end, I concluded that I was hardly a step closer to the visual fluidity which I desired.*

My conclusion was wrong. With mystical inadvertency, while pursuing my delight with obsolete but top quality ballistics control mechanisms (convertible into devices for generating visual fluidity), I discovered the **computer.** Moreover, my skill with these World War II analog problem solving machines, and a film[○] I had produced with the conversions, demonstrated a respectable command of analog computer graphic technology. IBM executives acknowledged this with a generous and extended series of research grants to pursue my quest for visual fluidity on a big computer.

To review briefly, I thought that any visual art, structured in time, would need some generative building block – an alphabet or scale. I asked repeatedly what visual elementals might match the scales of tones of music with which numberless musical constructs can be created, or the

*See Appendix, p. 183.

○ See my film *Catalog*, and Appendix, p. 167.

alphabets by which an infinity of ideas is constructed. Now that I was free to explore, I soon found that for the first time in history, visual periodicity and harmonics were accessible to dynamic manipulation through the instrument of computer graphics. These provided the clue to the following events.*

Of course, elaborate patterns of repetition and rhythm have been drawn, woven or chiseled into borders and decorations of all kinds since early ages. Considering arts techniques from the broad perspective of the present, I observed that the best "computer art" did not compare well with lacework from Belgium made a century ago. But the computer possessed a unique capability of making very complex pattern flow. One could plan exacting and explicit patterns of action and distinctive motions as intricate as lace, but in a way no Belgian lace maker would ever imagine.

I concluded that through digital constructions of pattern, harmonic considerations might provide the basis for a graphic art of motion. I also concluded that this power of the computer to liquefy pattern, allowing complex design to flow with control, more than justified the difficulties of computer technology, Finally, I determined that the relationships of sight and sound would be served best if it were possible to compose both components of an aural/visual work within some common aesthetic such as harmony would offer. All these potentialities lay before me, gathered within the central processor of any big computer with appropriate peripheral attachments.

A question remained: What computer, whose computer? Despite the continuing annual renewal of grants from IBM, I envisioned a time when, by the rapid growth of the electronics industry and the diminution of the size and cost of the components, I might own my own computer. However, for the present, despite the generosity of my sponsor, my work at computer facilities was assigned the lowest priority. I longed for a workable relation with the world of technology other than by intermittent, short-term grants of support.

At some time in the mid-sixties *ad hoc* committees within the art world were being formed to sponsor art and technology. I was im-

*See Appendix, p. 167, and Gene Youngblood, *Expanded Cinema* (New York, 1970).

mediately elated; my creative needs might be recognized and fulfilled. Then, just as quickly, I was discouraged by obtuse, confused or empty attitudes that developed among people of influence. Excitement grew over projects that were formulated with bandwagon haste around this subject. As a fad that came and went, along with so many others of that decade, the art/technology "boom" left in its wake as much prejudice as enlightenment.

The distribution of misunderstanding remained unchanged by all that effort on the part of artists, scientists, art museum curators and educators. Claes Oldenburg's gigantic icebag was perhaps a truer symbol than anyone guessed. The curious effort to co-mingle a few artists with a few huge corporations produced some exotic headaches. Of many art/philosophical projects undertaken to deal with the impact of technology upon the modern world, few were more ineffectual. By contrast, the Bauhaus, a school with a similar philosophy of technology and art, and similar influence upon the public, continues to grow as a subject of books and exhibitions around the world.

Over the centuries, the keyboard and other musical instruments were developed through a genuine cooperation between the fields of art and technology. This makes the recent project's failure to shape more favorable attitudes especially unfortunate, just when technologist and artist could have been collaborating, for example, on the instrumentation of electronic aural/visual arts and especially the dynamic control of video color phosphors. Of course, it remains a matter of greater importance that some deeper reconciliation and cooperation between art and science establish itself within this epoch.

Along with this neglect of many real issues of art and technology, there flourished the widespread fear of the computer as Golem and personal fears of being "folded, rolled, misplaced or spindled." These misapprehensions are still common. Many doubtful views became permanently fixed after the art and technology grants were distributed. It was, conspicuously, a period of "cybernetic wrongheadedness."

With regard to the use of the computer as an instrument for art, misunderstanding afflicted both extremes. Some looked upon the computer as an anathema capable only of sterile mechanization. Others believed the computer needed only to be "trained right" in order to take

over art productions.

At this time, a popular and misguided attitude (which may be related to Duchamp or the intellectual interests in the I Ching) led to a kind of rage for randomness, chance and change. Computers were somehow believed to be superb "calculators" of random numbers (a hopeless contradiction) and in turn, random numbers were believed to have mystical power with art (a serious possibility). With striking "logic" this favorite collegiate notion grew: that poetry and music, "just about everything" could be created with computers by using random numbers.

In the early seventies, a sizeable contingent of East Coast artists, intent on new careers, arrived at a West Coast institution because it looked as though the best opportunities with computers and technology and lasers (especially lasers) were at a new California "Bauhaus." Soon they were gone again. All this new technology, for these practicing artists, presented a choice between the raw and the cooked; they elected not to struggle with such unpalatabilities.

The early sixties had seen the beginning of a less transient movement of sorts, having to do with filmmaking as an individual artist's movement – underground. Here, as later with the art and technology mix (or mixup), I was both invited in and invited out of the activities. While the existence of an American film avant-garde was acknowledged, including a peculiarly West Coast contingent (my brother and I were members of the abstract branch) all was soon subsumed by New York.

There, in New York, film societies and spokesmen in both the press and books, were doing everything possible to recreate the atmosphere of Europe in the twenties. For a short part of that decade, in Paris and Berlin, some of the best artists, composers, poets and critics joined in what seems like a one-of-a-kind effort: to implant the artistic standard of their time into a very young technological film art.

The European effort was soon abandoned and in the New York of the sixties, it was never appreciated by the vanguard of American artists, composers, poets or critics. The idea remained always "beneath" the avant-garde. This particular idea of film artist – distinguished from actor or director of commercial movies – was taken up by a group that derived satisfaction from its self-relegation to an underground. It became an underground of film, filmmaker and audience. The underground audience

grew large because a few underground films shortly became synonymous with pioneering acts of sex, underclothed (without even a stitch of underclothes). Despite prudish outrage, this underground had its measure of success; it influenced the commercial motion pictures's way with sex and it even initiated a few of commercial television's rarely interesting new ways with design.

Yet to this day the idea of an independent artist's cinema remains ill-defined. There was hardly a movement, and the struggle to define one continues. It could be defined, of course, only by the existence of art works possessing the distinction of self-definition. The designation of film classic cannot be bestowed upon a film by a few writers, however much effort they commit to that end. Some work may achieve distinction. But it is too late to define an independent artist's cinema movement. The very depletion of silver resources and the sheer economics of film production, in competition with newer technologies, is bound to preclude that idea. What shall follow in its place? It will not be Polavision. It will be video.

It is video that renders the intermittent silver ribbon obsolete. Commercial film makers of course will follow their own destiny but the personal or independent "film artist" will surely abandon the film camera soon. All the projected sprocket holes, the dust and editing mechanics, lovingly incorporated into structuralist concepts of a generative grammar that derives from the materials of the media itself – all that will soon be relegated to the archives of museums. Selecting technical impedimenta of cinema, contrived deliberately for their films as a kind of self-conscious signing or symbology of the medium, fails to fulfill the function of a generative grammar. This class of film will seem rather quaint on future videodiscs.*

A tacit assumption of both the art/technology and cinema underground activities devolves from ideas of the generative grammar. Noam Chomsky has asked the two pertinent questions: first, can new grammars be synthesized and second, are music and art rightly, languages? As far as I can discover, he has answered neither question. I believe, of course,

*Regina Cornwell, "Progress – Discontinuous," *Artforum*, April, 1980, p. 60.
J. Hoberman, "The Cinema of Structure," *American Film*, June, 1980, p. 12.

there are ways to initiate a new language and a new grammar, but little in the contemporary arts leads us far in that direction. Little as I know about current efforts in this subject in Europe or the United States, I do observe a nimble disposition among the self-styled structuralist film-makers and the structuralist theoreticians in Europe. Structuralism's subsumption of information-theory was breathtaking; with these theoreticians, at least, it would seem that theory is mercurial.

Painting in this century discovered its structural elementals and its alphabet beneath its own burdensome impedimenta of style, representation and tableaux. Painting's basic structural elements proved to be, more or less, surface (canvas, support), pigment, shape, line and texture. For a decade, a coterie of cinema artists has strained to imitate their cousins, the painters, by creating their own dogma of structualist fundamentals for cinema – which turned out to be sprocket holes and such signing, signals and symbols of the technology. I abandoned cinema as a particular tool, seeking to create motion out of the basic elements of any graphic art – color, line, shape – consciously composing every detail of the frame area and, by transforming the details from frame to frame, to compose motion forward in time. This approach contrasts with the accepted editing practice of cinema (which merely splices given sums of frames) and it contrasts with accepted filming practice (which must arbitrarily film those frames). Neither practice modifies its own fixed "givens" which are preset and arbitrary, more or less. Neither cinema process can touch what should be the inner structural elementals of a visual art of motion.

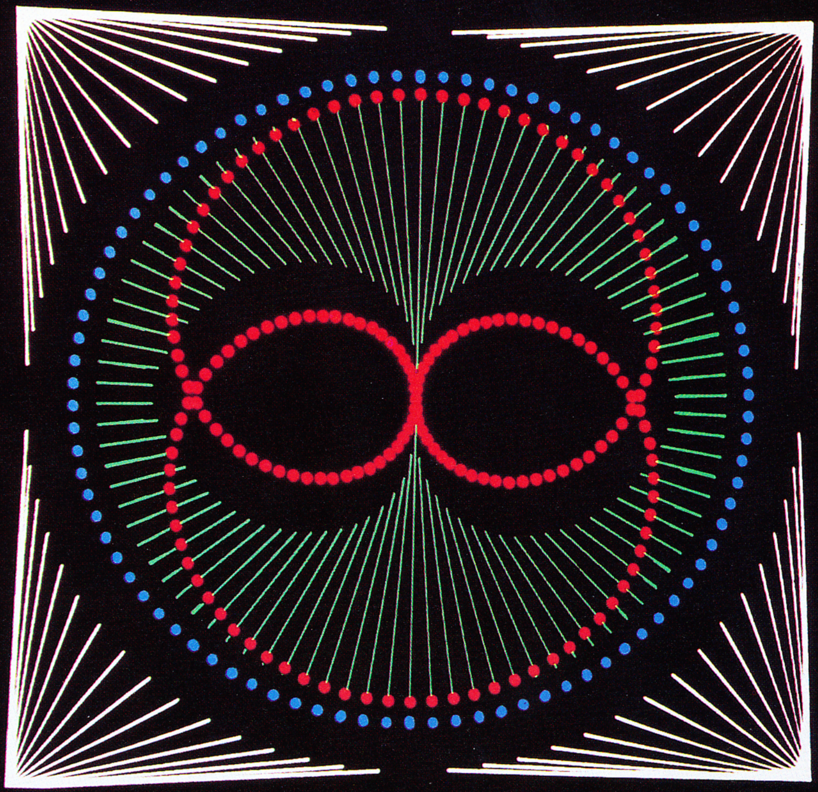
Nor can we touch the structural elementals of a visual art of motion (based upon criteria that will be defined within this book) through techniques of animation. For example, neither the hand nor the eye can manipulate, or simply keep count of, the hundreds upon hundreds of elements which move in accountable order and true orbital "counterpoint" in my own recent films, however "cool," "minimal" or "hard edged" some may wrongfully define my work. To deal with periodicity through digital harmonic structures, as outlined in this book, computer graphics are essential.

The problems of creating new grammar where none exists remain comprehensive and involve mysterious aesthetic norms. Basic assump-

tions need to be revised, but few persons recognize this. When an ambitious would-be artist elects to start afresh among the fields of scientific technologies, he starts fresh, **after** his art school training. So it was with independent filmmakers. Paraphrasing Winston Churchill (the artist) once more: Never before had so many elected to fly such difficult flying machines with so few flying lessons. The few safe landings and the carnage were both predictable.

It is not the time and this is not the place for summarizing this activity in the arts, especially technology's arts, over the past twenty or thirty years. These matters are never summarized well and this is, least of all, my responsibility. The framework of my ideas has passed from collisions with technology and collisions with many attitudes presuming to deal with art and technology, to a serene perspective on both the perils and rewards of new instruments and instrumentalities for music and art.

Yet my aspirations have been consistent since that shipboard tussle with my visionary glimpse of music in the viewfinder on the high seas bound for Rotterdam. Whether I have found a valid grammar rooted in late twentieth-century technology remains to be seen. These first chapters have provided background for what is to follow. I submit the remainder of this book for its suggestions regarding the novel **idea** of a new grammar and for an art that looks like music. This new grammar must speak to us as eloquently as music or fail its very reason for existence.



Chapter IV

The Problem: How Shall Motion Pattern Time?

The Raft of the Medusa, a painting by Theodore Géricault is a tableau of disaster, a scene of pandemonium: under turbulent sky and a thrashing sea, survivors struggle just to remain upon the pitching topsides of a gigantic raft, or to aid one another while some slip under the waves even as the distant rescue vessel is in sight. No spare surface within the canvas is untouched by violent motion and emotion. Nevertheless, Jackson Pollock's fields of abstraction are of an order that would imply still greater activity. His gestural act of painting produces a surface of three-dimensional turbulence. Where, in art, do you find more motion than this? And what is the nature and function of motion in all art? What are the relations of motion and emotion?

A quest for answers to questions such as these led me to study the nature of time and motion in prior visual arts dealing with the visual elements that contribute to a singular design. A painting, regardless of implicit dynamics, still exists passively fixed in time. But a new art might pattern action in time with all elements in motion at all times. The graphic problem, then, will be how to manipulate a field of visual elements so that all parts will contribute purposely to some temporal (time-structured) design.

In this era, preoccupations with action painting, process in art, serialization, pattern, optical phenomena, color fields and light itself, all significantly reflect intensified concern with problems of the dynamics of painting.* Within the community of visual artists, few painters since Kan-

*Popper, *Kinetic Art;* and Rickey, *Constructivism.*

dinsky have remained indifferent to the problem of "time" and "motion" in their still medium. Yet most remained uninterested or innocent of the knowledge that technology lately could provide the possibility of working with real time and real motion; hence their concern with the dynamics of their static medium is in one sense outmoded. The distant rescue vessel figuratively will never arrive in Géricault's canvas drama.

"As a tone in itself is not yet a melody, so a chord in itself is not yet harmony ... Music is motion – tonal motion as melody – chordal motion as harmony."* "A note – A, B, C, D, and so on – has no meaning in itself; it is just a note. It is the combination of the notes which can create music."○ These are truisms about music, but for me they are more: they possess certain fragments of insight with which to approach the problem of visual motion.

An early intuition about how to control total dynamics led me to activate all graphic elements through a motion function that advances each element differentially. For example, if one element were set to move at a given rate, the next element might be moved two times that rate. Then the third would move at three times that rate and so on. Each element would move at a different rate and in a different direction within the field of action. So long as all elements obey a rule of direction and rate, and none drifts about aimlessly or randomly, then pattern configurations form and reform. This is harmonic resonance, and it echoes musical harmony, stated in explicit terms. I tried this procedure in several films, and was gratified by the consistency of the confirmation it demonstrated. □

Ironically, multiplane animation – the only other differential function ever applied to graphics – is a leap in reverse, because it actually serves to fixate an illusion of the stasis of the natural world by a trick that gives realistic looking differential motions to foreground, middleground and background. Géricault's various paintings of violence and action show that motion depicted as an event upon this earth is of an order quite different from the conception of motion in the mind's eye, for example, as implied in the turbulent abstractions of Jackson Pollock. At

*Victor Zuckerkandl, *Sound and Symbol* (New York, 1956), p. 109.
○ Claude Levi-Strauss, *Myth and Meaning* (New York, 1979), p. 52.
□ See the films which are illustrated in Figures (6)–(12), pp. 75–80.

the same time, a look at the "real world" demonstrates the static relationship of foreground and background, and the static relation of mountain to sea, tree to house, regardless of the activity thereabout.

My early intuition about the problem was correct in visualizing a field of action as Gestalt patterns of moving elements and not as a stage upon which motion events occur. Traditional pattern is constructed from a repertoire of elements. For example, lattices, Islamic mosaics and borders are patterns constructed from elements – stitches, tiles, bricks, beads or brush strokes. The problem of motion, then, directed my attention from the idea of merely rendering an overall landscape as a static stage for motion. I thought to borrow from these traditional practices of pattern construction. I thought of the rhythm of pattern. So, as if they were pattern rhythms in actual motion, I conceived of ways to manipulate a series, family or scale of elements, each with its own action potential. The problem of motion is less like painting landscape and more like herding sheep, or hedgehogs, as in Alice's croquet.

Continuing to study the problem by comparing prior arts, I asked myself: what are the essential components of time and temporal organization in poetry, dance and music? Metrical order is an important part of the structure of poetry as it is important to harmonic structure of music. Pitch pattern and rhythmic pattern are interrelated and interwoven in music just as syllabic, rhythmic pattern and meaning interweave in poetry.

Twentieth-century art, poetry and music again and again have breached the thoroughly codified rules of meter and harmony. Still, a latter-day ambivalence emerges, perhaps to reign. "The king is dead. Long live the king!" could become a refreshing idea. A late twentieth-century attitude might claim that meter is dead; long live meter! Stravinsky pronounced that harmony is dead; he might have added – long live harmony! Perhaps an end is near to the tiresome reaction against all nineteenth-century giants in the arts and their academies. Within the earliest decades of this century, Dada did a job that was needed. But recent **reaction** in art – anti-art, anti-meter, John Cage's effort to prove that even a squeaking chair knows structure and is therefore "music" – all of this has grown ever more tedious and inappropriate.

Nearly everyone senses the presence or absence of meter. Regarding

meter and rhythm: "Both are always present simultaneously – the uniformity of the wave, the variegated pattern of durations, of long and short, in the actual succession of tones. Both together make up the rhythm of our music – not the succession of longer and shorter tones as such, but their succession supported, borne along by, the rise and fall of the continuing metric wave."* Reducing to these words what is instantly felt by the vast majority of mankind (especially the young child) hints at the unfathomable subtlety of the perceptual processes at work within the metrical patterning of time.

Despite seconds and minutes, time is not naturally marked into units; and despite motion picture frames, motion is not broken into static frame units. "We cannot draw boundary lines on a wave; one wave passes into another without a break."○ My quest for understanding intensified my struggle with seemingly simple problems such as how the mechanical demarcations of frames can be reconciled with the variability of musical rhythm.

I tried to define and manipulate arrays of graphic elements, intending to discover their laws of harmonic relationships. I hoped to sketch the outline of a foundation for metrical order. Early efforts to deal with this problem employed differential functions applied to the motions of each of the elements, as noted above; but other problems radiated in all directions around my primary suppositions.

Overwhelmed by the erudition of musical textbook detail and technique and humbled by my floundering with the staggering graphic problems, nevertheless, I started at last to make some progress. A benchmark was reached when I began to apprehend the relationship of the three terms: **differential, resonance** and **harmony.** First, motion becomes pattern if objects move *differentially.* Second, a resolution to order in patterns of motion occurs at points of *resonance.* And third, this resolution at resonant events, especially at the whole number ratios, characterizes the differential resonant phenomena of visual *harmony.* □

* Zuckerkandl, *Sound and Symbol,* p. 171.

○ Zuckerkandl, p. 170.

□ Looking back upon my experience of this "rite of initiation," I wonder if the composer himself might gain insight were he, too, able to look beyond orthodox harmony into this unconditionally unorthodox view of the Pythagorian "physics" which transcends particularity to define, in the broadest generalized sense, **the harmony,** namely the resonances of differential periodicity.

I had discovered the many significant meanings of the word *resolve*. Among the eighteen numbered definitions in my dictionary are, "to make a firm decision about," "to find a solution to," "to deal with conclusively," "release," or this sixteenth item in the dictionary: "*Music.* to progress from dissonance to a consonance." What is more definitive than "release" of tension? What else than "to find a solution to?" What else than exactly what I found in my visual harmonic resonances? This resolve at a resonant event dissipates tension. Dissonance reaches consonance at any moment of resonance. All this is exactly as visible as it is audible. I felt that this was to be a profound discovery.

It followed that if moments of resonance resolve tension, certain factors must be at work as complementary forces to build tension. Though I little understood the details, it seemed clear I had discovered a clue to a force-field of visual perception. What I knew about music confirmed for me that emotion derives from the force-fields of musical structuring in tension and motion. **Structured motion begets emotion.** This, now, is true in a visual world, as it is a truism of music.

My search for a scale or alphabet was stimulated at this time by Noam Chomsky's book, *Language and Mind.* There I read, almost as a fact incidental to the point of his writing, a quotation from the text of the Port Royal *Grammar,* a seventeenth-century view of language: "... [we] make infinite use of finite means [with our alphabet]... that marvelous invention by which we construct from twenty-five or thirty sounds an infinity of expressions."*

It was not at all clear what might constitute the computer's graphic "alphabet." Yet Chomsky's brief history of the devious directions taken in a search for an understanding of the origins and the nature of language stimulated my endeavor, where perhaps the very scope of that search should have been discouraging. I felt wiser and derived confidence in my own quest, having learned of the succession of wrong turns and blind alleys that have already been taken in classic scientific studies. Chomsky's description of a major turn in a wrong direction that was pursued for more than a century by a large faction of linguists led me to wonder if a considerable faction of composers in this century might have

*Noam Chomsky, *Language and Mind* (New York, 1968), p. 18.

taken a similar turn in some wrong directions.

I sensed that Chomsky's concept of the deep structure of language applied almost miraculously to music.* The details did not seem important. I was encouraged just to know that there was speculation about "innate human dispositions" in regard to our speech competence. Therefore it appeared to me that musical dispositions must surely follow. I entertained the outrageous presumption of leaping beyond all constraint of logic to conceive a visual world of harmony to which there must be innate human responses, just as in the aural world of music.

Reflecting further, I observed that language, this greatest and most complex intellectual achievement of collective mankind, came to us "naturally," so to speak. Nobody, no committee planned a babel of tongues. In fact, efforts to synthesize, improve upon or even redirect the development of any language have always floundered. (French grammarians have merely struggled against "Franglais.") Whatever parallels exist between language and music are bound to include the probability that music, too, would defy synthesis by plan or committee – or by myself, of course. Such thoughts somewhat tempered my reflections on the very idea of innovation in art.

Yet I began to discover the dynamics of graphic pattern arrays and their harmonic interrelationships. I began to detect the subtle charge and discharge of tension related to order/disorder dynamics in these arrays. The problem now seemed to define itself in such terms. I was beginning to conceive of the basis for a graphic "scale" evolving from harmonies, and I saw that here was a way beyond the monolithic emotional stasis of so much abstract film and video with which I was familiar.

For years, I had detested a quality of stasis that permeated and spoiled a broad variety of pattern in motion compositions. Video wallpaper or video-Valium are two of the more popular "expletives" used frequently with no slight derision to express what I had observed. The emotional blandness of these films derives from a pattern of movement that neither gathers nor discharges tension. Many films exhibit total ignorance of the function of tension. Forces at work in an image moving

*In the first three chapters of *The Unanswered Question*, Leonard Bernstein grasped the metaphor in deep-structure of linguistics *vis a vis* music much as I did.

without purpose cancel one another. This becomes a ludicrous stand-off of force/counterforce, an equilibrium of pointlessness even while the screen may boil with activity. Now it was obvious: only **structured** motion begets emotion.

The composer – mindlessly, intuitively or with careful deliberation – concatenates one element of harmonic cohesion onto another and another. And so he builds structures which literally lead us by the ear along a pathway of emotional continuity. I became acutely aware that these forces prevail whether classical harmony or "atonal" musical constructions were involved. With insight transformed since my earliest filmstrip experiments, I now grasped the pervasive function of harmony: I could feel harmonic forces either working or failing to work in every graphic dynamic, whether the motion had been structured knowingly or not.

Now I objected to the word "abstract" because it serves to misdirect emphasis onto the object that moves and so to obscure the idea of motion as dynamic pattern. Dynamics interested me in the sense that music is motion, tonal motion, chordal motion. Here, abstraction is not at issue. Any image must be an ephemeral conveyance of patterns of motion. Within their limits of mass and inertia, dancers also perform "musical" patterns of motion, and of course the human body is hardly an abstraction.

My early distress with "film symphonies" came to mind. The determination to find a more fluid vision than was possible by using a cine camera pointed at the world (rivets in iron plate on the high sea) continued as the subject of much reflection. By contrast the recurring resonant events with computed differential structures of elements in motion were producing valid, generative and fluid patterns. I was satisfied that here was the beginning of an architecture of motion that might be made to blossom the way musical architectonic pattern blossomed, in the Baroque era for instance.

At the same time as I gained new control of fluid graphic harmony, some composers in search of new musical resources were beginning to compose with magnetic tape and electronic synthesizers; but their "new" compositions were often immobilized through loss of harmonic structural control. Mono-melodic, sustained tones and tiresome slow

motions became cliches that often dominated electronic music from mid-twentieth century onward.

It seemed, ironically, as if their loss was my gain. Just as my new way beyond stasis of the graphic field through applied harmonics came into view, many electronic music composers seemed to lose touch with harmonic fundamentals and dynamic pattern and seemed to lose dexterity of figuration. The natural fluidity of music seemed to thicken to molasses, in their aural electronic world.

On the other hand, as my graphic elements progressed through one point of resonance or through a fraction of a harmonic cycle, motion was indeed patterned. When, infrequently, one of the sequences in my harmonic films was composed effectively, the results of these resonances or this cycling, were characterized by a diversity of rise and fall of tension, of highs and lows of tension, and a metrical rhythm and order such as we expect and receive everywhere within the vast diversity of pre-electronic music.

Among other practical considerations these observations resulted in a decision. For the time being, I elected to put aside the musical problem as it bore upon my own long-term plans while I would concentrate upon new prospects for optical differential dynamics. I would settle for whatever music I might find for each new graphic composition since my optical studies were the immediate challenge.

Clearly, the study of electronic and computer musical potentials would be far more generously endowed than my graphic work. At universities and electronic music centers around the world, long established funding of music studies had been generous. Investment in the newest electronic instruments went on and on despite a new-to-obsolete life cycle of about three years, throughout the past thirty years.

With a plan and a perspective upon the past and a sense of future, the direction of my life work was now clarified. Here is a summary of the problem as I found it:

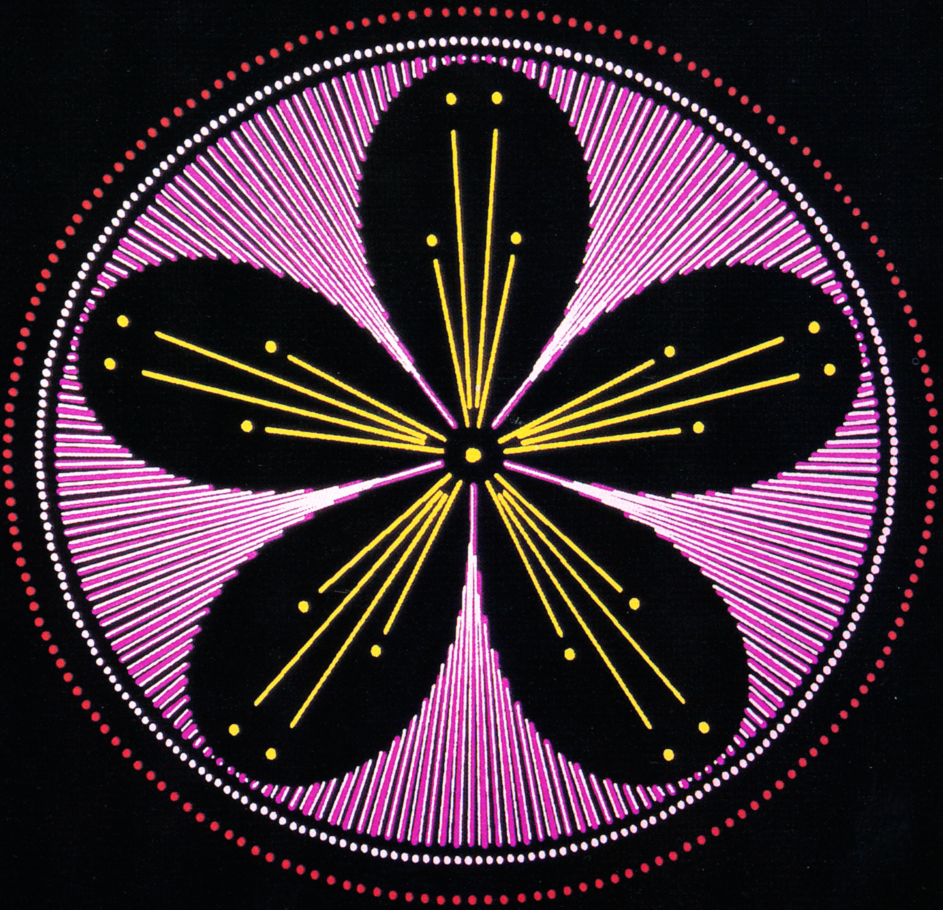
Music, as the true model of temporal structure, is most worthy of study among prior arts. Music is the supreme example of movement become pattern. Music is time given sublime shape. If for no other reason than its universality and its status in the collective mind, music invites imitation. A visual art should give the same superior shape to the temporal

order that we expect of music. As with the twenty-six elements of the alphabet, music's hierarchical pattern of tones provide the model for a visual art with which to "make infinite use of finite means" to construct "architecture."

The unassailable fact remains that a work whose principal dimension is time must faultlessly reckon with time. The only way we can deal with time is to construct along time's dimension. There are ways to give shape to time's rule upon human experience. This means that there are ways to anticipate the next moment and to gratify expectations raised by the moment just past; for example, in the human experience of music, expectations do arise moment by moment. As listeners, we are engaged in a musical intercourse with the composer. How we engage him, and are engaged in turn by the composer, marks the very life of the matter of music.

The problem, then, of a visual art of motion centers on that same vital engagement. The dialogue between composer and whoever responds to his work is tied somehow to a give and take, step for step in time. This is what we mean by "giving shape to time." "Music is temporal art in the special sense that in it, time reveals itself to experience."* Otherwise time is shapeless or mechanical or lifeless, or time is fixed into catatonic rigidity.

*Zuckerkandl, *Sound and Symbol,* p. 200.



Chapter V

The Instrument
Not Pure Hypothesis – Not a Piano

The following is a description of an instrument capable of producing patterns of movement of visual elements within a graphic pattern field. These movement structures derive from the changing harmonic relationships of elements that move within a two- or three-dimensional field. This instrument provides a composer with a means to compose a visual art of movement pattern whose primary structural dimension is time.

A composition may be stored on film, video tape, disc or other storage means. It may be played out in real time to a laser deflector or video projection means for a "live" performance. Music is a logical "accompaniment" and color is an important parameter with any of these procedures. The training and skill required of the composer may be compared with that of his musical counterpart. One version of the instrument would include a digital music composing capability in order to facilitate composition of aural/visual interrelationships.

We know the audio spectrum extends from, say, 20 Hz to 20,000 Hz. Upon this field, numerous musical scales of all cultures are mapped in various steps of harmonic ratio. We can imagine a scale of steps in one dimension from low to high. A visual analogy of this one-dimensional musical spectrum might be a two-dimensional coordinate field with 20,000 X by 20,000 Y coordinate units.

Let us try to visualize this field. Without considering what the object might be, we could move "something" from the lower left to upper right in this two-dimensional, imaginary field, as music moves from low to high. Or the movement could follow the pathways of the conductor's baton or hands as he directs the music. Of course, the bouncing ball

touching each word of the song, reading left to right as the music moves in time, is an old sing-along game of the early movies that is suggestive of these motions.

Throughout a century of color organ experiments and even more frequently since the invention of the oscilloscope, would-be music/image innovators have attempted to invent a device with which to play color "musically" on this two-dimensional field. Many minds have contrived to associate the rise and fall of melody with the upper and lower regions of this field and thereon to lay out visual "scales."*

As a functional playing ground for a visual analogue of the musical spectrum, this simplistic idea is invalid. Only vaguely do we associate musical scales with "up or down," and we seldom associate tonal motion with action to the left or right.

Again we may consider the conductor: There is no exact correspondence of the motions of his hands with the rise and fall of musical pitch even though there must be some kind of relationship between the music and his stressful actions; Not all that energy is an act for the benefit of the audience behind him. Otherwise he would communicate only tempo to the orchestra members by standing before them, flailing the air, as it seems. A further discussion of this subject occurs later.

The instrument proposed here is based upon a different scaling principle which is mapped onto its own field in a manner that avoids the questionable up-down, or left-right analogy. The scale ascends, as do the musical scales, but not "up" and "down" either X or Y field coordinates.

The scaling principle is crucial to understanding the nature of this instrument. Some discussion will be required to grasp the functions which generate graphic pattern by differential motion. This type of motion pattern was inconceivable before the computer made possible the control of visual periodic pattern. Therefore a description of differential motion pattern will follow. The diagrams on page 50 Figure (1) are for this purpose.○

Given 60 points set in a row, as in Column A – Frame 1, move point #1 one step up, point #2 two steps up, point #3 three steps up,

*See Chapter II, p. 22 (Reference to animator's attempts to "illustrate" music).
○ See Chapter XII for a detailed description of the programming needed to produce these illustrations.

and so on to point #60 which is moved sixty steps upward. Frame 2 shows these moves. Frame 3 shows point #1 moved two steps, #2 four steps, #3 six steps, *etc.* Frames 4 through 9 continue this simple progress. At Frame 9, point #1 has moved eight steps upward while point #60 has moved 480 steps (8x60).

This action sequence is the simplest example of a differential motion pattern. I stress **motion** pattern because the motion itself is patterned significantly. Although the static image on the page is pattern too, it is the pattern of movement exclusively that matters. As the following columns hint, the potential for pattern by differential motion is widely variable.

Column B is an application of differential motion to a line of points at various radii of a polar coordinate layout. Point #1 is at the mean radius. Point #60 is at the extreme radius of a circular polar coordinate field. Again, as in the first example, the horizontal line of points are moved in incremental steps derived from their number, 1 through 60. In this column, progress of the movement is merely clockwise around the circular field, starting at three o'clock instead of upward as in Column A. Column B, Frames 2 through 9, show how the identical rule of Column A produces a different pattern.

Column D is an application of this differential motion to an array of triangles which demonstrates that the principle applies to any set of elements, not just points. The triangles are graduated in size and located in superimposed position initially. Otherwise the differential rule of movement according to each one's number is the same as in columns A and B. In this instance 24 triangles are moved differentially around a common circle, with clockwise motion from twelve o'clock.

This is the differential principle which is applied in various ways to all motion of typical scales of an hypothetical instrument. Any scale ascends a ladder of tensional structure in the time dimension. The progressive rise and fall of tension, which I might call the force-field pattern of a structure, is characterized by recurrent nodes, where tension is resolved to equilibrium (resonance). This attribute of tension, within any differentially dynamic structure, will be described at length later and with more illustrations.

For now, one further detail to consider: were Column B continued for

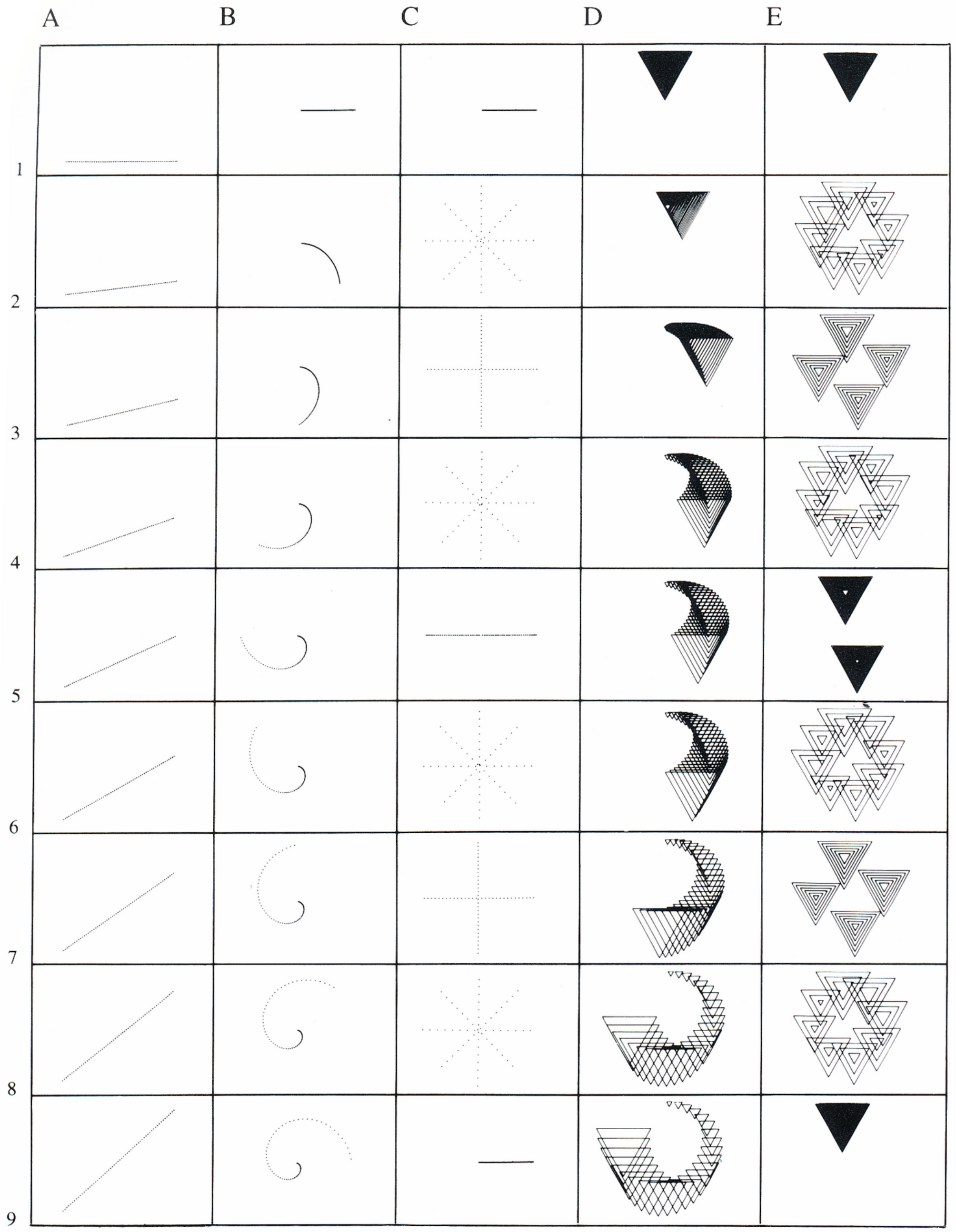


Figure 1

the proper number of steps, all 60 points would return to an exact repeat of their initial starting position. When point #1 has completed one cycle around the circle of its radius, point #2 will have completed two, #3 will have completed three, and #60 will have completed its sixty cycles. A selection of a few of the simple fractional steps, the low order fractions of the entire cycle, are shown in Column C. In like manner, the same fractions of the triangles of Column D are extended throughout one cycle in Column E. The fractions shown are the eighth, quarter, three-eighths, half, five-eighths, three-quarters, seven-eighths and the return repeat to zero.

I conclude this preliminary description of differential motion with a look at another cyclical pattern of movement. Figure (2) p. 52 is a line plot schematization of this fundamental principle of **digital harmony.** It represents a graph of the pathways of twelve points that move through sine function curves. Again, as with the differential motions of the Figure (1) examples, point #1 moves one cycle, point #2 moves two cycles, point #3 three cycles and so on to point #12 which has moved twelve cycles. The cycles begin and conclude with all twelve points superimposed. In other words, each sine plot, one to twelve, fits within the same overall span, while the amplitude of each is diminished proportionally to its number.*

All scales ascend a differential progression of resonant nodes. These nodes are also called **beats** or harmonics or beat frequency nodes, which occur at various fractional intervals along any ascending progression of periodic phenomena. They are events, in time, of resonant pattern that take form by virtue of the hierarchy of elements which are mapped onto a polar or Cartesian coordinate system. From another point of view, differential dynamics presents a new action specific of all the commonplace phenomenon that is best known as moiré interference pattern. Interference, or moiré, are simply other terms for visual periodic resonance.

Figure (2) the line plot, shows its harmonic nodes clearly at each fraction. Column E of Figure (1) (the continuation of Column D) and Column C (which continues B) display their event patterns of harmonic

*The placement of do, re, mi *etc.* of the solmization notation will be explained on page 69 in Chapter VI.

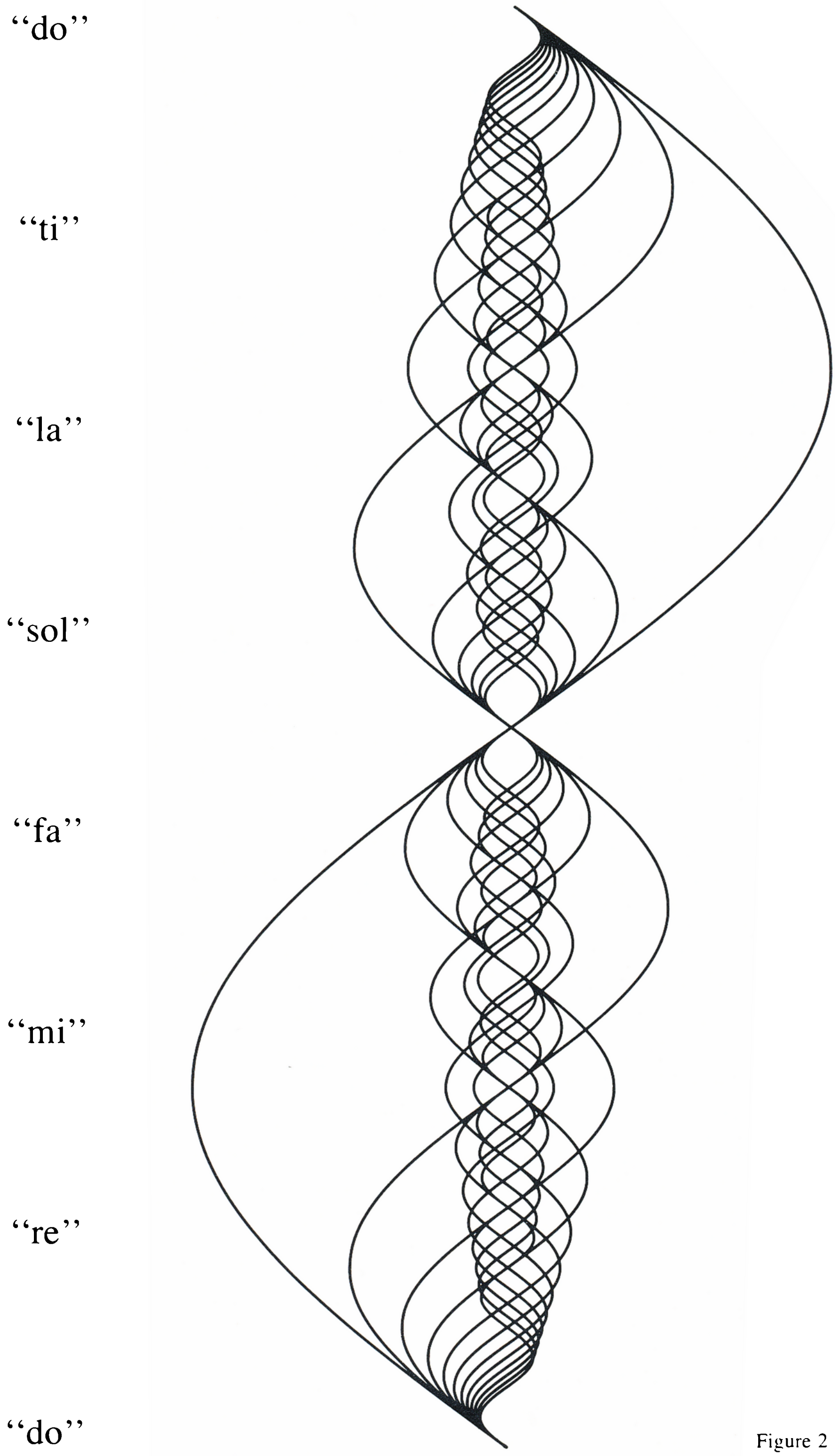


Figure 2

resonance, or beats all generated by the progress of differential dynamics.

Figures (1) and (2) have served to illustrate some elementary ideas concerning differential dynamics. The paragraphs to follow will outline the basics of the prototype graphic instrument. This prototype is assumed to represent only one of a class of instrumentalities for differentially dynamic pattern. The few illustrations of this entire book provide merely a hint of the diversity of pattern which can be envisioned. The scope of this variability should be likened to the diversity of the world's music which is derived entirely from a few simple intervals of audio harmonic relationships as they constitute the tunings of the vast numbers and classes of musical instruments around the world.

Two major differential parameters that determine event patterns are employed in our instrument. These parameters are identified as "RD," a radius differential factor, and "TD" (theta), an angular differential factor, to be described later. Both parameters distribute or map the various elements by controlling their relative spacing with differential motion. Stretching the spacing of elements by the progress of differential motion affects overall harmonic relationships which produce the resonant patterns of the elements. The elements may consist of points or lines, or constructs which may be made out of points or lines, as for example the triangles above (at Figure 1, column D) or any pixel (picture element) component.*

Stretching the spacing of elements may be illustrated by imagining a ribbon of rubber upon which a series of marks are layed out at equal distances. As the ribbon is stretched by pulling from the ends, the spacing between each mark (element) is extended equally. Whatever way this ribbon is wrapped or spiralled or otherwise distributed within a field, back and forth, around or meander, we can imagine this progressive stretching to affect all the spacing of the elements equally. Also, we can imagine that the change in spacing produces changing patterns of distribution over all the field.

From the beginnings of music in prehistory, we have experienced pattern which the ear perceives as the harmony (linear and simultaneous) of music. In that same way, these graphic motion harmonics are per-

*See also Figure (12), p. 80.

ceived visually. Harmonic considerations dominate the composer's choice of notes that sound at any exact time. While a melody consists of a sequence of notes, the effect is a pattern of movement that is more or less continuous regardless of the rapidity or slowness of the sequence, or the length or shortness of the successive intervals.

A melody is an entity vastly greater than the sum of its notes. An objective of melodic design is a structural totality whose progress from beginning to end is one indivisible continuity. A simile for this is the word which composers of the European romantic periods have used often and appropriately – miracle.

This miraculous entity is often a tonal pattern which departs from a point of tonal stability, and however it negotiates the push and pull of forces of harmonic energies, in a kind of game, it will most likely end with a return to some form of original consonance or to the tonic.

Harmony, consonance-dissonance, order-disorder, tension-resolution are interrelated terms in the lexicon of music. They are relevant in this field. For the game is the same, namely to design visual pattern constructs as a dynamic interplay of force augmenting force, ultimately embodying the singular attributes of melody, continuity and integrity. All this, when it happens, as it does with some great music, is justifiably, if only poetically, termed a "miracle."

The instrumental concept being described here allows that dynamic interplay of visual pattern. The composer may select from a branching tree of pattern-choice at any metric or harmonic juncture of a composition. Thus, he may choose to construct from infinite options the pattern of tensional ebb and flow to suit his conceptions and his meaning and purpose. The least unit of time accessible to the composer in this visual domain is much the same as in music. Yet, as a comparison, the structural units are longer than the unit we call a note of music. They are like subsets of melody, comparable with musical motifs or phrases.

"A note... has no meaning in itself."* It is the combination of notes that make music. Likewise, one frame of these patterns has no meaning. This idea is more difficult to accept; we are mislead by the movies. A still from a movie may show Douglas Fairbanks at mid-thrust in a duel

*Levi-Strauss, *Myth and Meaning*, p. 52.

with death itself. That "frame" is a picture worth its thousand words. A frame of these patterns speaks too few of the thousand words. Sounding an A minor chord or striking A above Middle C "has no meaning in itself" and tells us too little, say, about a sonata by Mozart. Just so, a frame of one of these patterns "has no meaning in itself" and tells us too little about the action.

The "RD" and "TD" parameters of a prototype instrument delineate the two-dimensional force-field upon which a "scale" is drawn. We observed that musical scales are distributed upon the spectrum of the aural field which ranges linearly within limits of hearing. As that single dimension of pitch frequency is a linear continuum, so by contrast our visual field provides the idea of a **two-**dimensional, **planar** continuum, a planar field whose coordinates are, in this instance, "RD" and "TD."

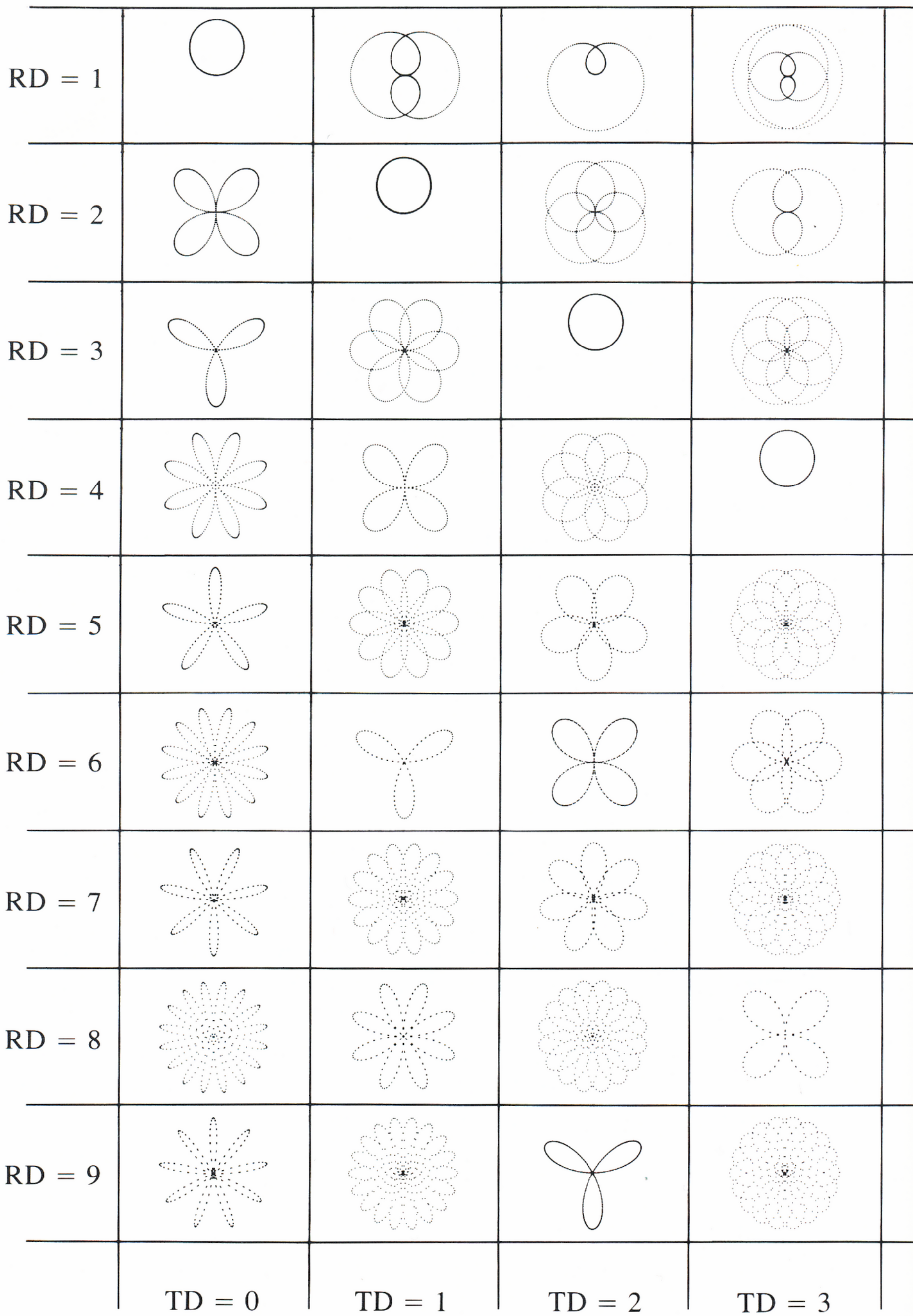
On the musical-linear continuum, notes of a scale are mapped, each at its own pitch, as determined by harmonic ratio rules of succession. With our visual-planar continuum, certain conjuncts of the "RD" and "TD" parameters can be mapped. These form a graphic "scale," determined by harmonic rules, or determinants, which are valid in the sense that notes of music are valid. However the horizontal (time) *vs.* vertical (chordal) distinctions, which are common to music, are interwoven in this graphic domain.

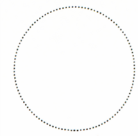
The planar field must not be mistaken for an actual field. This visual display is rhetorical – the theory, as distinguished from the practice. It is a mathematical conception which, in turn, can be mapped onto any visual field, including any three-dimensional space, by employment of a large variety of different projections and transformations. There can be diverse projections such as the polar or Cartesian coordinates or topological surface projections, or spatial projections such as illustrated in Figure (12),* each of which would produce a different pattern, and different patterns of force. Likewise, the notes of the musical scale are merely rhetorical until they are "mapped" onto any of the diverse instruments of the world, by merely tuning that instrument to some conventional scale or to its own unique scale.

The illustration on pages 56–57, Figure (3) is a typical mapping of

*See the description of this illustration on p. 81.

Figure 3





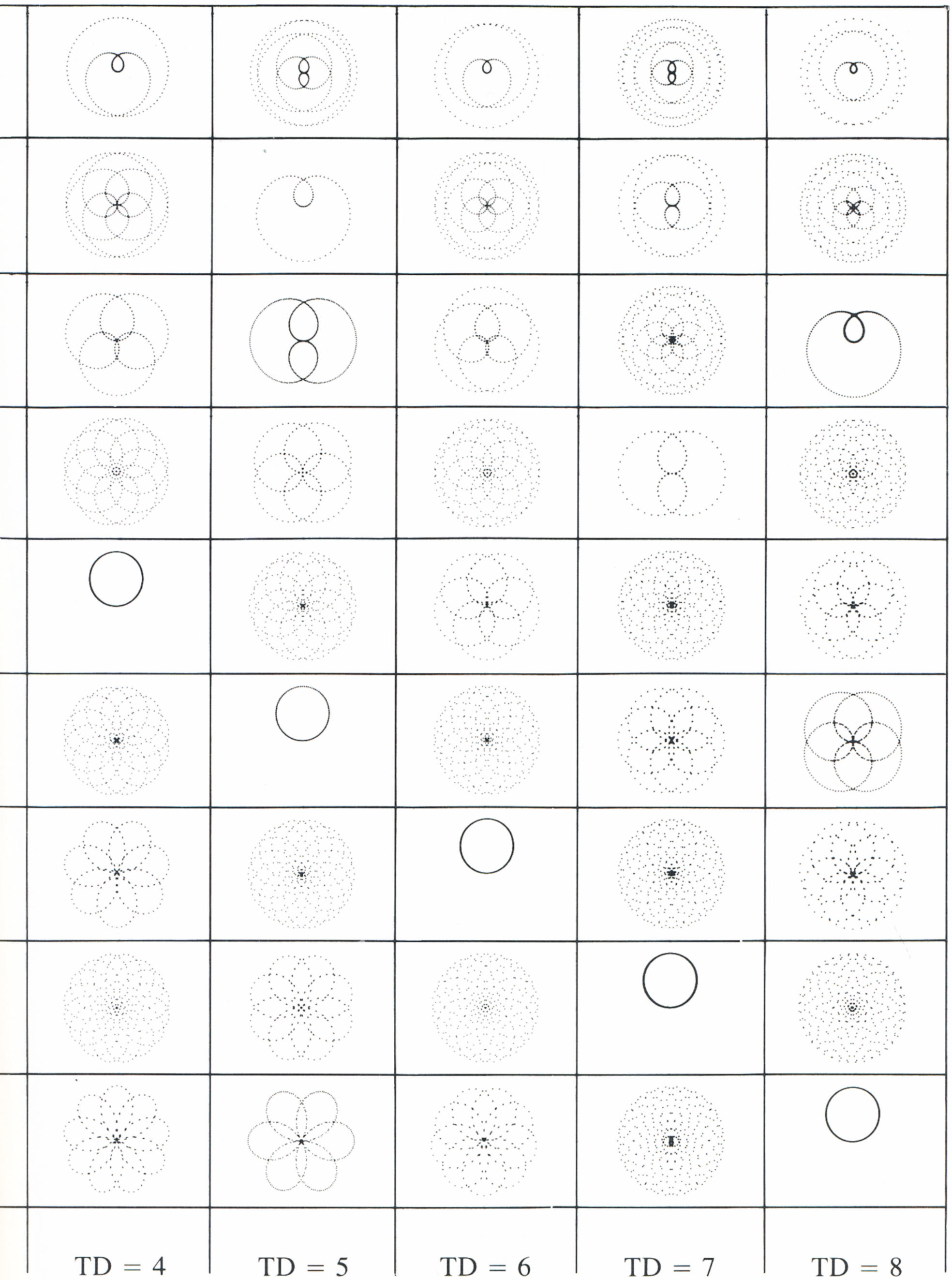
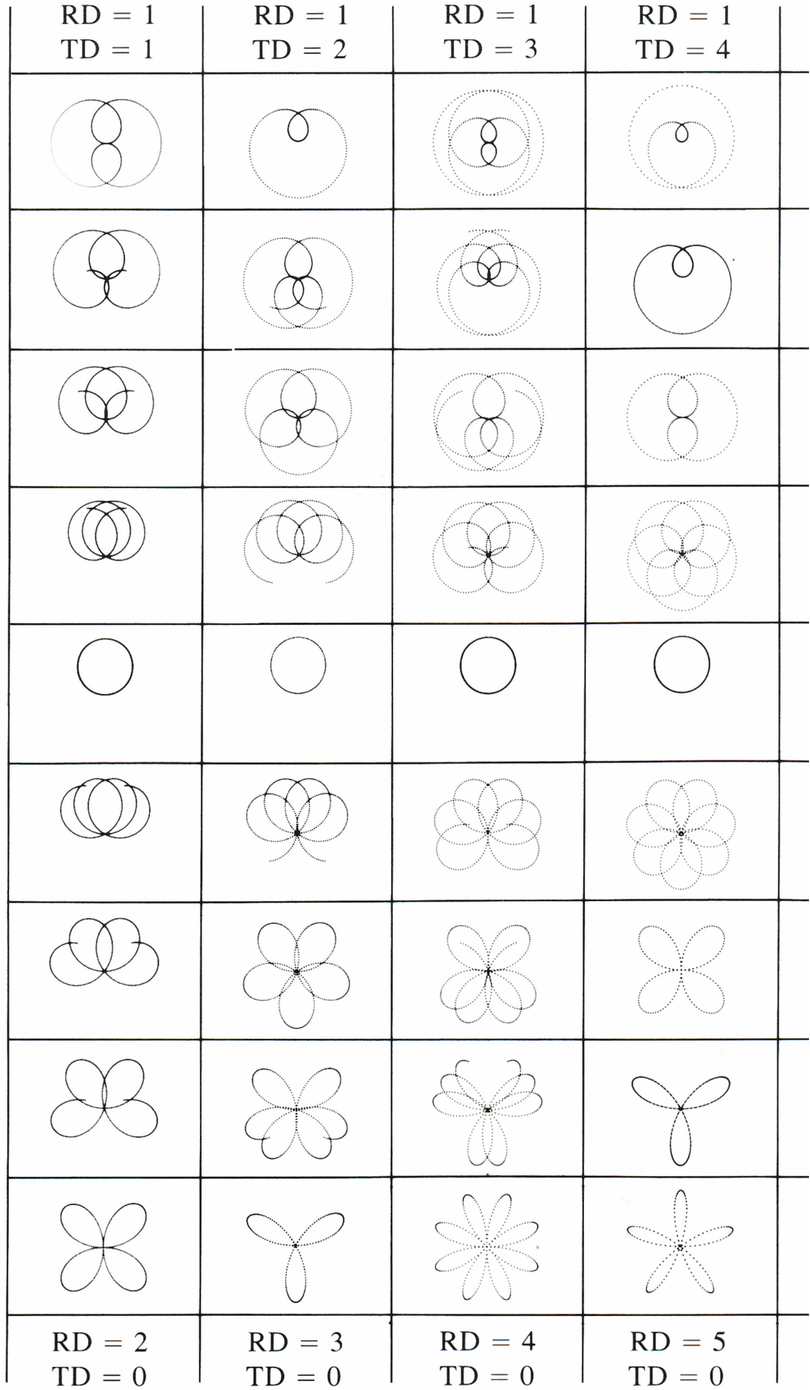
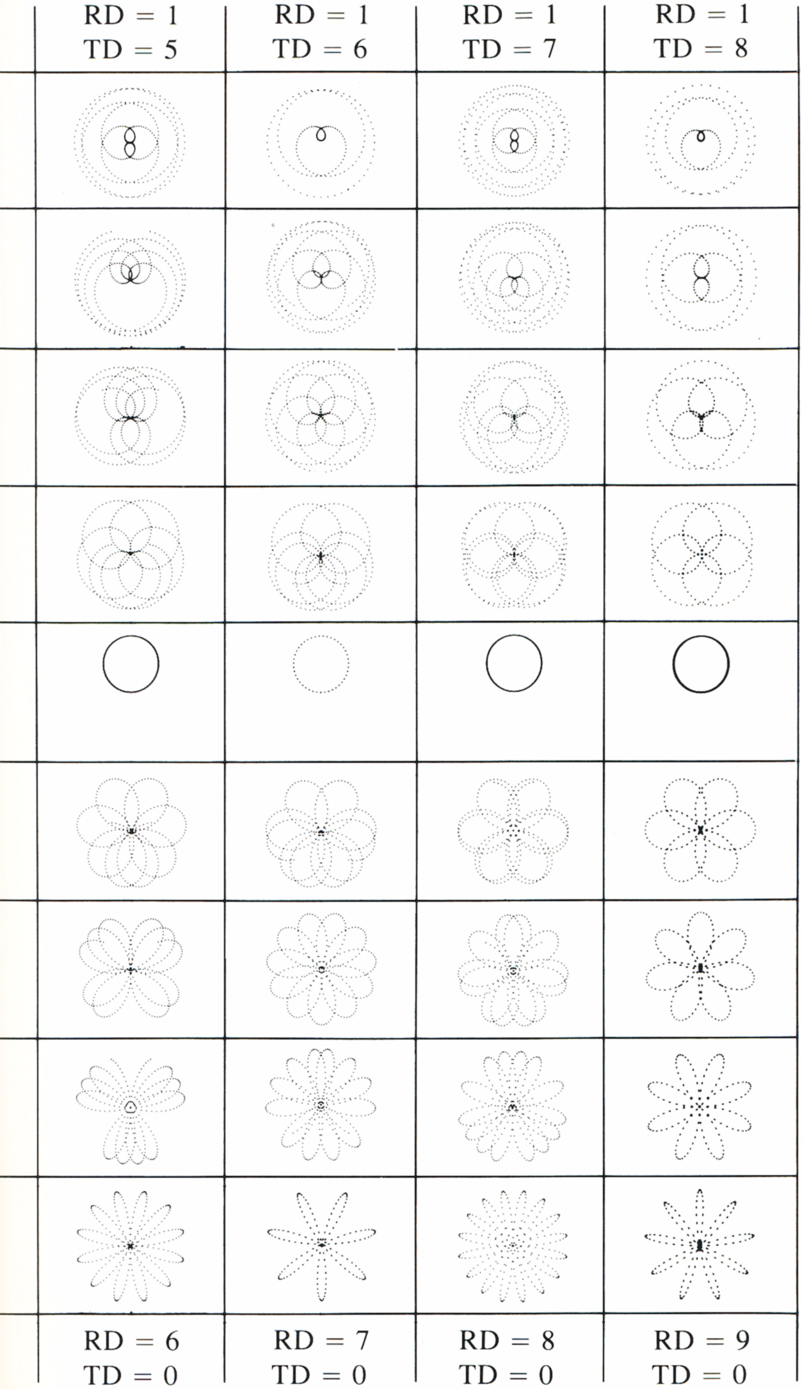
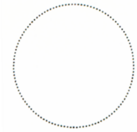

TD = 4
TD = 5
TD = 6
TD = 7
TD = 8

Figure 4




RD = 1
TD = 5
RD = 1
TD = 6
RD = 1
TD = 7
RD = 1
TD = 8
RD = 6
TD = 0
RD = 7
TD = 0
RD = 8
TD = 0
RD = 9
TD = 0



conjuncts of "RD" and "TD." The horizontal coordinates consist of "TD" units spaced at integers, zero through eight. "RD" is mapped vertically at integers one through nine. The composer is free to move from any frame on this array to any other in as many or as few steps as he may choose. He may move step by step. Or the nature of the scale is such that he may move from here to there by continuous action. Between one image and any other in the illustrations of Figures (3) or (4) 1, 10, 100 or 1000 frames might be generated by the program. Continuous motion from frame to frame would likely be modulated by acceleration and deceleration at departures and arrivals.

Figure (4) illustrates the flexibility of choice with another example. Columns 1 through 8 consist of the following sequence of steps: TD=1 to 0 × RD=1 to 2; TD=2 to 0 × RD=1 to 3; TD=3 to 0 × RD=1 to 4; and so on up to, TD=8 to 0 × RD=1 to 9.

More of the characteristics of this so-called scale-field are revealed by these two illustrations. Note that a simple circle, tangent to the center point of all the other patterns, recurs consistently on a diagonal across the array of Figure (3). Note that other repeated or echo patterns radiate at other angles. In Figure (4) this circle occurs each time at step five, because the steps here are derived from coordinate values that are located at steps on the diagonal of the array of Figure (3), in nine steps for each of the Figure (4) columns. Note, too, that all nine steps cover different space on the array of Figure (3). This will serve to emphasize that both illustrations represent arbitrary steps on a plane which is, in fact, a stepless continuum.

The idea of steps in a continuum is one that needs thought and special attention. The continuum is stepless until the selection of a frequency value is made. Once made, a string of consequences follows automatically; the entire family of intervals related to the first selection falls into place. One can deduce from this the status before and after the first choice. Out of the void, so to speak, a complete tensional heirarchy of structural elements is given substantiality by the one singular decision. Of course, all pattern would be totally different if another element instead of points were employed or if another coordinate geometry were devised. There is potentially great variety of pattern by each choice with each parameter and every geometric configuration. Obviously, the op-

tions are infinite as they are to the composer of music.

What is not illustrated in the figures, and cannot be illustrated except by the most extended stretch of imagination (action obviously cannot be illustrated, only "schematized"), is the hierarchy of tensional force distributed about a scale-field. Tension is resolved in its own way. Somehow tension is gained and lost in a way which, at the same time, does and does not comply with any exact analogue of the tonic force of music. For example, tension is resolved when any action arrives at that circle in both illustrations. This, incidentally, is an ideal correspondent for the function of the tonic in music.

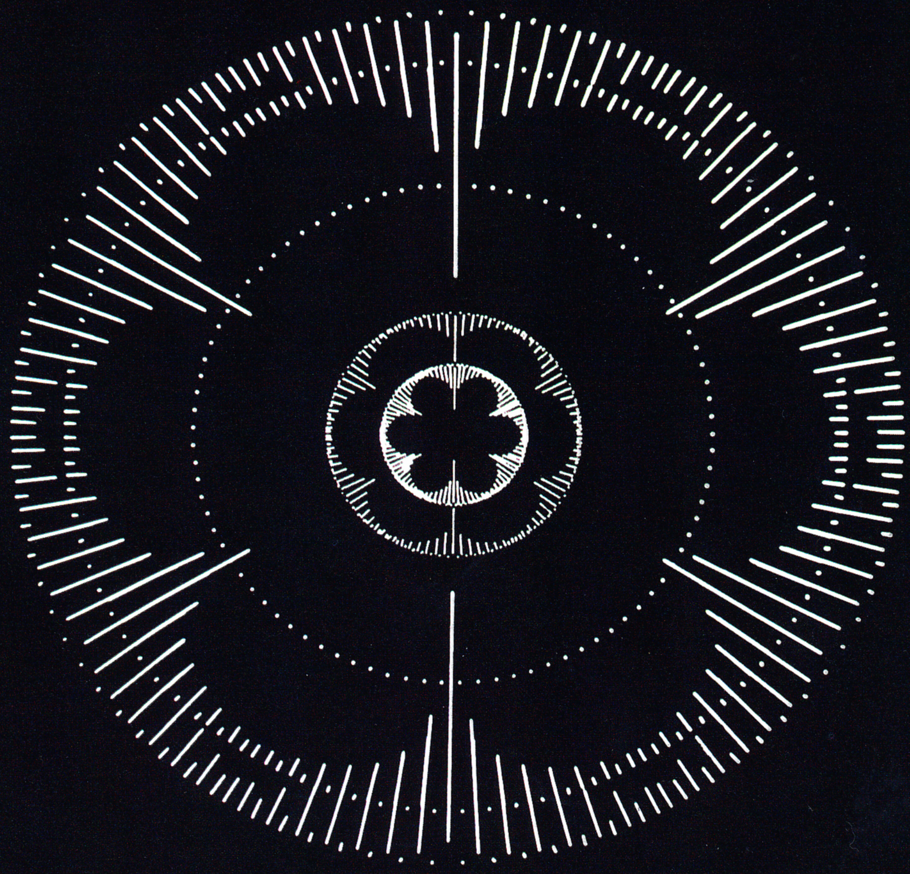
The "flip book" on the upper corners of the pages of this book is a sentimental return to an early device for the depiction of movement. Holding the book in one hand while flipping through as many pages as one can, will reveal a pattern of motion. The complete sequence which is repeated throughout the book is a cycle representing the motion of one "octave." More on this will be found on pages 68–69. To observe the movement fully, one should try the flipping motions over and over in order to accumulate a sense of the total action, which reads forward or in reverse.

At this point in the description it may be worth adding another footnote regarding the very idea of freely associated words and my free use of words such as force, tension, tonic, tone, motion and emotion. Usage, however, will bear me out. We speak of bodily tone as well as musical tone. Obviously tone, tonic and tension have more than simply musical usage. Consider once more the conductor. There are, in his performance, physical, bodily and musical similes, all working at once. Conducting symphonic works demands tension, exertion, perception, musical experience and sweat.

The graphic "tonic" mentioned above is not an analogue to the aural benchmark. It would be misleading to make such a claim. It would confuse issues regarding distinctions within aural/optical relationships at a time when there is need for clarification and definition. There are few analogues of sound to image. At this time, there is only a very high potential of technical capability for a fruitful partnership in a world in which we are only beginning to find some fortuitous complementarities.

This chapter has presented an opening set of generalized descriptions.

I must apologize for interlacing them with reference, comparison and metaphor from music. Some readers may wonder if there might not be a better way to discuss a new subject without constant reference to an old one. I apologize. I have found no better way to discuss a totally new subject without comparing it to some existent subject about which we share common knowledge. Moreover we are viewing a body of graphic phenomena that is complementary to musical phenomena. While it was little known until recently, complementary relationships of music and computer graphics represent a new use for the term complementarity. In the next chapter the nature of this complementarity will be defined further and explored. The partnership of graphics with music may prove to be as interesting as the videodisc where it surely belongs.



Chapter VI

The Idea of Differential Dynamics Pythagoras Revisited

The differential parameters TD and RD can be explained in more detail as follows: given a set of elements such as many points, or a number of hexagons, circles or wire figure cubes, any of these will be moved differentially about the picture field. See Figures (3) through (12). The effect of differential movement of these or any other elements, as stated above, means that if one element moves at X-rate, #2 element moves at 2X-rate, #3 at 3X, #4 at 4X, and so on.

These are the mechanics of differential dynamics. As I use the term harmony to denote the ratio order of both the horizontal and vertical structure of music, I use this term, "differential dynamics" to evoke, in the optical world, the nearest analogy to the term harmony. In the following paragraphs I will try to explain basic principles in detail and pinpoint the similarities to and differences from musical harmony.

Parameters "TD" and "RD" determine differential action. "TD" controls motion in the theta or angular dimension of a polar coordinate distribution. Otherwise "TD" might affect the X-coordinate of a Cartesian translation of the same coordinates. "RD" controls the radius of a polar array or the Y-coordinate of a Cartesian plot. Of course, there could be a "ZD" parameter determining a third coordinate for a volumetric field, and other parameters.

When a number of points constitute the given graphic elements employed on a polar coordinate layout, the combined functions of "TD" and "RD" in the program's equation generate the family of patterns of which samples are shown in Figures (3) and (4).

If we were to move from 0 to 1 by "TD" or "RD" (or both), this

would produce an advance of one whole number of pattern progress. Such an advance produces a significant dynamic development within the pattern as suggested by various steps in either Figures (3) or (4).

As remarked before, it is a subtle problem to explain the exact effect of these dynamics without presenting a moving sequence on film or video.* Yet, what transpires – what is depicted here in the graphic pattern of action from one to another harmonic node – is probably the best possible schematic representation, or simply a kind of "diagram," of its parallel in the dynamics of musical harmony.

Audio and optical scales show many similarities and obvious differences of pattern dynamics. For example, assign a value of 1 to some arbitrary musical frequency, then 2 may follow, and 3 and so on. Between 1 and 2, of course, lies an infinite number but, the interval represented by the ratio of 1 to 2 is the primary harmonic relationship of music, namely the octave. Yet this fundamental interval of music possesses a puzzling variety of qualities which are totally unparalleled by any aspect of graphics.

Briefly I'll try to contrast some particular qualities of the musical octave *vs.* optical intervals. One need only sing a few notes here and there within two octaves for an experiment.

First of all, one can't sing an image. With the aid of a projector of some sort, one can state a visual action in real time, so to speak, as a performance comparable to singing. One may run a sequence on a moviola, for example. This differs from dance; it's a matter of physics. The performer experiences dance as an obvious musical feeling, but the body is a real entity in the real world and it is subject to mass and the physical laws of inertial forces that hardly affect the subtle musical waves in air or the visual image on a CRT display. It's as if even the lightest human body were forever expelled from music's space where air and light are free to dance.

Second, although there are octave repeats in the visual field, they are different in ways which I will attempt to demonstrate later. For the sake of comparison, sing do, re, mi, fa, sol, la, ti – then pause. One will sense the strong "gravitational" pull that urges the final sound of do^2, the

*See the "flip book" on the pages of this book.

octave above the first. The gravitational pull of the musical octave is, at one and the same time, powerful and obvious.

Third, while singing the octave higher, observe the increase in muscular tension of throat and thorax. A significant source of the built-in tensional hierarchy within all musical structures, this is not obvious with images. Of course, this muscular tension is intimately involved with dance.

Finally, for a different perspective on these ideas, one may repeat R. B. Fuller's question about higher or lower: Which way is up for the traveller in space outside the geometrical coordinates of Earth's gravitational field?* Likewise, how do we conceive these coordinates within the inner ear? Which way is the musical up if the questioner is upside down? So there is some confusion usually in our conception of the rise and fall of pitch, on the one hand, and "higher" and "lower" tension, on the other.

Higher and lower, as terms in music have meanings which relate more to qualities of tension than direction. Departure from the tonic, whether up or down in pitch direction, is more often than not unequivocally upward (increasing) in tension. Tension is, by far, the more subtle and pervasive quality of music. A descending line of a musical figure often ascends tensionally before it is allowed to resolve (descend) to a conclusion.

With the Tchaikovsky symphonies, for example, to plot the course of tension, as against pitch direction, is as simple as a, b, c. His musical designs often consist of progressions of rising tensions which parallel rising pitch; then both forces turn downhill, so to speak, to resolve.

Richard Wagner, in the opera *Tristan and Isolde,* has complicated this pattern a hundredfold. The resolution of a statement has become act and scene of the drama. The circuitous resolution of a harmonic proposition is delayed, postponed, restated with ambivalence and innuendo, then prolonged and extended. All the while tension – roll upon roll of waves of tension and emotion – subtly accumulates, being sustained and prolonged. All the while complexity and uncertainty rise and fall with the melodic line. Finally, after all this strained craving for resolution, we

*"Introduction" to Youngblood, *Expanded Cinema*, p. 17.

sense merely passing incidental resolutions of the harmony, even as the curtain closes on the scene.

With what is known today, graphics offer few comparisons with music of European civilization, even from the tenth century onward, especially the music of Wagner, Mahler, Debussy, or Schoenberg's, Webern's and Alban Berg's sophisticated chromatic "atonal" innovations. Obviously our current state of knowledge of graphic harmony is hardly that mature. However, no criticism or offhand objections are adequate to discredit the many similarities between audio phenomena and what is known of the graphic characteristics. For there are similarities, familial in quality, that may be exactly right for the complementarity of a partnership of image and sound.

For further study of similarities and differences, note Figure (5) pp. 70–71. Perhaps these unorthodox graphic "illustrations" of music's resolve to tonic are pertinent. Possibly one only needs a diagram to support the idea of tonic gravity; but this will need more explanation.

The pattern of order/disorder is the singular dynamic force which has its effect upon both our visual and aural perceptions. Evolution to and from greater and lesser complexity – this is the force of harmony that gives shape to time. Figure (5) is a step-for-step record of that process expressed in simple terms of evolving (dynamic) pattern complexity. Column 7 of Figure (5) is reproduced in the flip-book. One should study this motion on the flipped pages thoroughly. One can observe that the effect is alike in either direction, just as it is with the musical scale – up or down. And one may observe a sense of resolve at either end.

As schematized variously in the columns of Figure (5), or once again in the flip-book, the interval between whole numbers displays an obvious departure from simplicity toward pattern complexity. Midway between one and the other, the action begins to change, to retrogress, away from complexity. Though not to the identical starting point, the patterns return to a similar quality of simplicity. In fact, simplicity is not exactly descriptive of these dynamics. The thrust is more toward purity and focus of pattern. To reiterate, the drive of the action does not reverse; the "feel" of the sequence is directionally forward all the way. No point between departure and arrival compares with the simplicity of the end points. This action reminds one, unequivocally, of the cyclical progress

of: do, re, mi, fa, sol, la, ti, do^2. The flip-book is designed to illustrate this quality of the action.

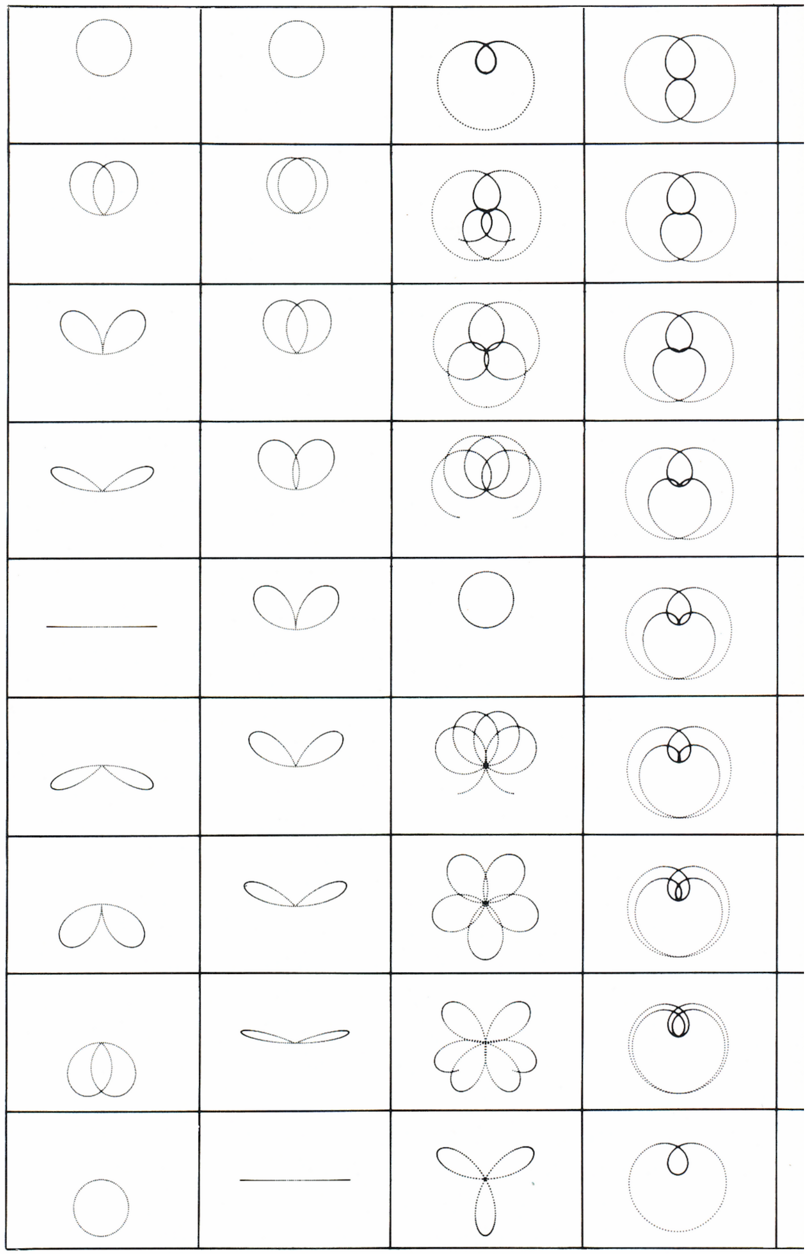
There is no one-to-one correspondence intended by placing the seven solmization syllables – "do", "re", "mi" *etc.* – at the side of the nine-frame illustrations of Figure (5). They provide a metaphor. One is asked merely to compare the similarity of the feeling of this "image scale" and a traditional musical scale in the light of the ideas expressed on these pages. Likewise the solmization scale is metaphorically suggestive when laid alongside the sine curve pattern of Figure (2) p. 52. This sound/image juxtaposition is an appropriate symbol for the single hypothesis of this book; I have elected to create the symbol, featured on the cover, for the idea of aural/visual **complementarity.**

It is impossible to understand completely this aspect of the idea of musical experience of time. "Do-re-mi" begin a progressive sequence in time. "La-ti-do^2" end the experience by way of an approximate mirror image. The first and the second do possess a special and unique interrelationship – the octave ratio of one-to-two pitch. This whole number ratio is so distinctive to ear or eye, that even neighboring pitches – even ti, or re – have the power to point to, or gravitate toward, their respective adjacent tonic if the "sense" of the tonic is well established. These nearby tones, and the graphic model, might suggest the idea of leading-tones, although in musical terminology, only ti is so-called.

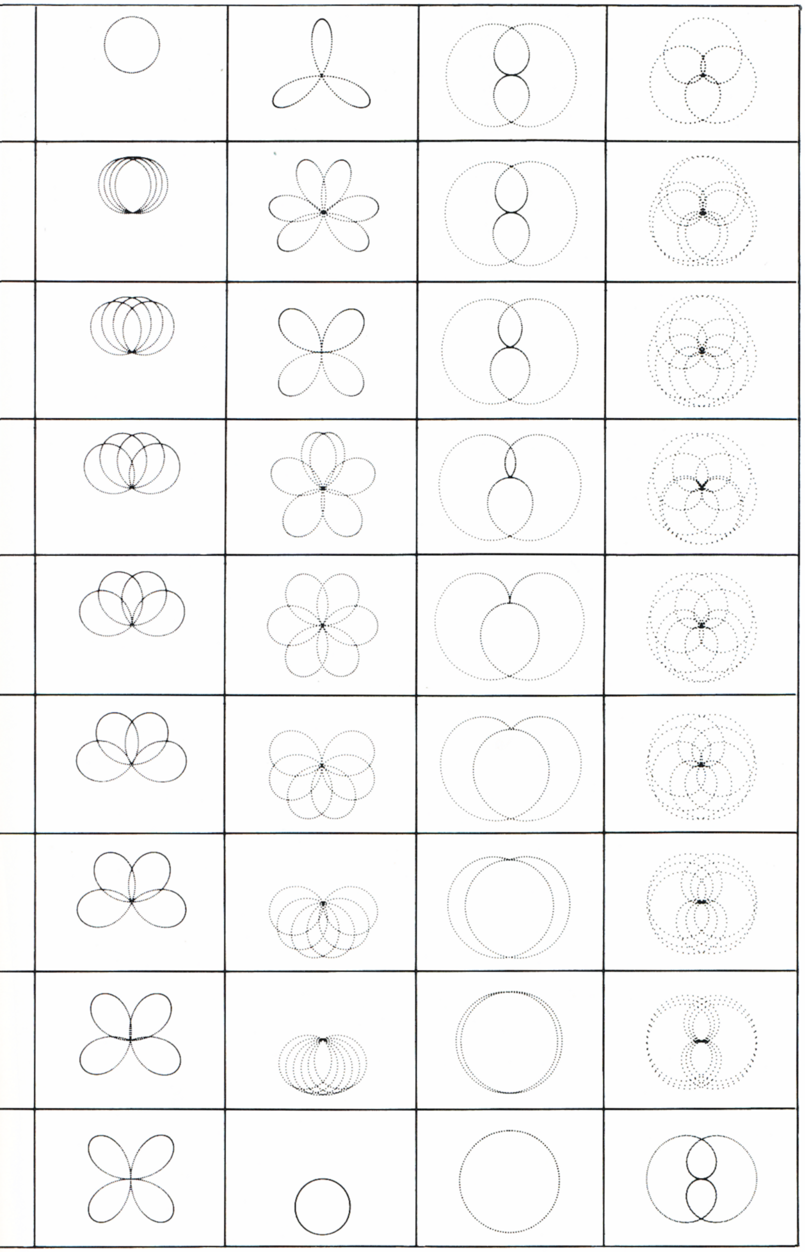
There is another point that must be stressed: all the above imperfect illustrations are descriptions of process in time. Sing do, re, mi, fa, sol, la, ti – – – then delay – – – do^2 too long. Of course, the gravitational pull will "leak away" out of the experience. Time is of the essence in all this. The subject here is about the nature of patterns of time in human perceptual experience. The illustrations, on the page, in ink, illustrate stasis and fail totally to show the pattern of time as experience. Hence the flip-book is presented to "illustrate" motion.

That particular quality, often referred to as the **drive** of a piece of music, is almost automatically enhanced with metrical or cyclical consistency and repetition. Rock musicians know this – perhaps too well. On the other hand, the most difficult visual quality to compose into a composition, as every abstract filmmaker may know, is the same driving propulsive thrust with a visually rhythmic metrical cycle.

Figure 5



RD = 1
TD = 1



"do"
"re"
"mi"
"fa"
"sol"
"la"
"ti"
"do"

RD=1
TD=0

The washerwoman ascending the stone steps in *Ballet Mécanique* is a film loop printed as a strip.* As she reaches the top step carrying her enormous laundry bundle the film loop ends, at which point it is spliced, so she starts the climb over again, and again, and again. Her prodigious "performance" is unforgettable as an example of driving visual rhythm. But the loop has a mechanical meter which looks as a motorboat might sound. No other loop in any film since has been quite that hilarious. This is probably because any film loop, or any computer loop, for that matter, is mechanically redundant, simplistic and obvious. Too often loops fail to generate that special quality of music which I will call its drive. Instead they generate tedium which is exactly the opposite of "drive."

It is not obvious to everyone that rhythm does not repeat like gears or loops, turning round and round.○ The charm of *Ballet Mécanique* has to do with the century's earliest delights with the newness of the machine in art – typewriters, airplanes, sirens and jazz. Its charm is hardly in the film's innovations with rhythm.

The abstract filmmaker should wonder why it is so difficult to produce any kind of profound rhythmical sophistication. This century's avant-garde obsessions with free verse or free rhythm (read a-rhythmic), and an equal distaste for metrical symmetry (though it is everywhere in pop music), are attitudes that dull one's receptivity to rhythmic subtlety. Filmmakers in fact have never known rhythmical order as elegant as a simple nursery tune. Otherwise, it would be more broadly appreciated that rhythmic order begins with – and is generally an intricate subfunction of – harmonic structure.

Consider the following regarding the way graphic harmonics may affect rhythmic pattern. The advance from a "TD" value of 1 to 2 as in Figure (3), can be followed by a jump back to 1. Were this to be repeated over and over, the effect would be like the charwoman on the film loop – mechanical. But the advance from 1 to 2 could reverse from 2 back to 1. Now this would look like a child's two fingers playing C – D – C – D – C – D – C on the keyboard. Neither this child nor that "TD" motion need sound or look mechanical. Nor will either generate drive or much

* Standish D. Lawder, *The Cubist Cinema* (New York, 1975) p. 199.

○ It is significant that Terry Riley, Philip Glass and Steve Reich, whose music may seem mechanically repetitious, are not in the least misguided by easy mechanical rhythmic devices.

excitement, for very subtle reasons which are beside the point.

We may introduce upon this tedious motion of "TD" values from 1 to 2, a changing value for "RD," say from 1 to 2 to 3 to 1. If we alternate "TD" between 1 and 2, and we add the three-step cycle of "RD," the result is a quantum leap in rhythmic novelty and subtlety. With a structure no more complex than this, we introduce to the visual world a kind of rhythmical sophistication which is taken for granted in music although it is unprecedented still in visual art or film.

Other examples abound of tentative gains in understanding of optical meter and rhythm – and new discoveries. Melodic lines in music often are described in terms of drive or forward motion which at another moment in their development, may seem to pause temporarily, then resume their forward motion. The forward propulsion of a melody is related to tensional pull and thrust, a function of the hierarchy of harmonic relationships. An early exploratory example of this same pull and push of pause and forward drive is found in some sequences of the film *Arabesque.**

The ear, which can discriminate subtle pitch differences, will compare and sense a frequency ratio of two-to-one as the most obvious and strongest pattern of quantized simplicity (resonance) within any range of the sounding patterns of two tones. Tuning of instruments consists of listening for frequency interference beats, and "tuning them in." Visually we need only observe the oscilloscope pattern to confirm this. Resonance is visible.

Does this suffice in explaining a rudimentary principle of harmony, a subject of considerable study by physicist and composer alike? Certainly not, but here at least is a useful hypothetical graphic schema to apply, at will, to visual compositions, a principle that may encompass no more than order-disorder relationships.

From intuition, and firsthand experience with my own films and my experiments, I am convinced that the eye and ear are about equally receptive to the dynamics of order/disorder phenomena. Aspects of the gigantic subject of harmony will be modeled and studied in the future as visual phenomena with the aid of harmonic functions in computer graphics. Particular computer graphic procedures with dynamic differential pattern will contribute techniques toward understanding related aspects

*See analysis of *Arabesque*, Chapter IX, pp. 98–99.

of perception.

Differential control of motion, whether or not explainable by order/disorder principles, does impart pattern and order. All elements of this visual domain gather and disperse with corresponding tensional charge and discharge. It is a test of the skill of a composer in this optical world that he search out unique ways with harmonics to give a shape to the new potential of pattern dynamics. So it has been for centuries with the composer of music, a part of whose genius is his agility and invention within the universe of harmonic pattern manipulation.

Figures (6), through (12) suggest only a few of my earliest efforts at invention. Each figure is a sequence of frames which have been culled from much longer sequences taken from my own film studies. Each of these study compositions explores a simple idea. That is, each is a study of the results of selecting a set of parameters that will determine the dynamic aspects of a sequence.

Figure (6) is an illustration of the results of selecting a triangle as the elementary unit and a circle as the matrix pathway while juxtaposing clockwise and counterclockwise circular action to produce symmetry. The progress of the sets of elements along the matrix pathway is illustrated by selecting some of the harmonic nodes, or resonant points. *(Matrix III)*

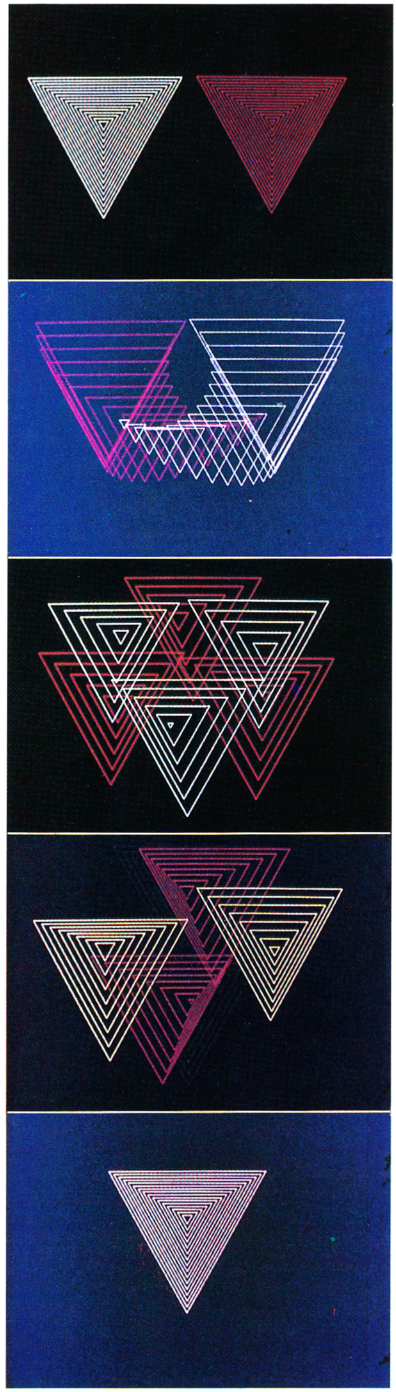


Figure 6

Figure (7) presents some of the symmetrical patterns which are the result of the progress of 24 squares around an elaborate three-dimensional Lissajous figure (invisible) which is the pathway of their motion. *(Matrix)*

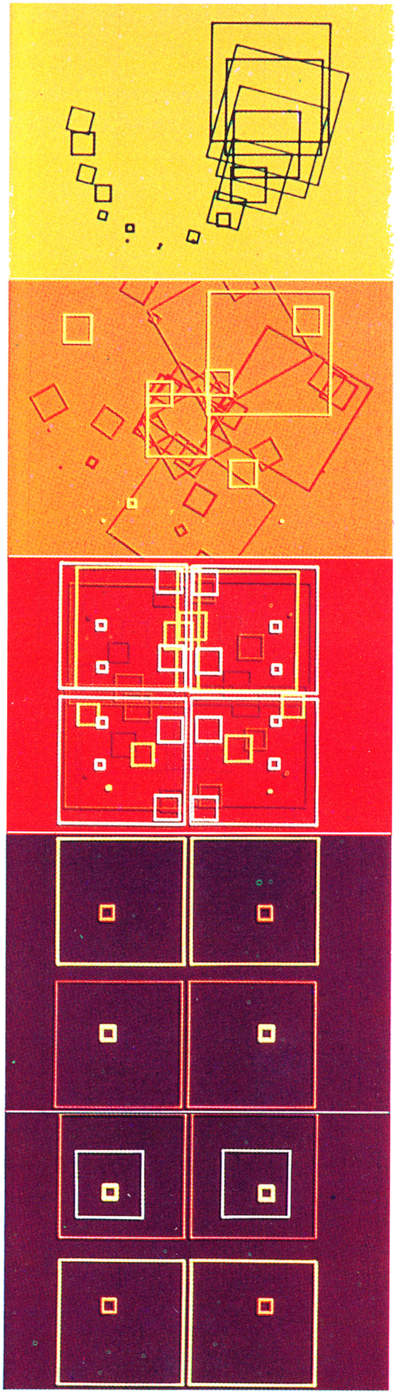


Figure 7

Figure (8) is a selection of frames from another section of the same film. Twenty-four wire-figure cubes move around the same Lissajous pathway as above. *(Matrix)*

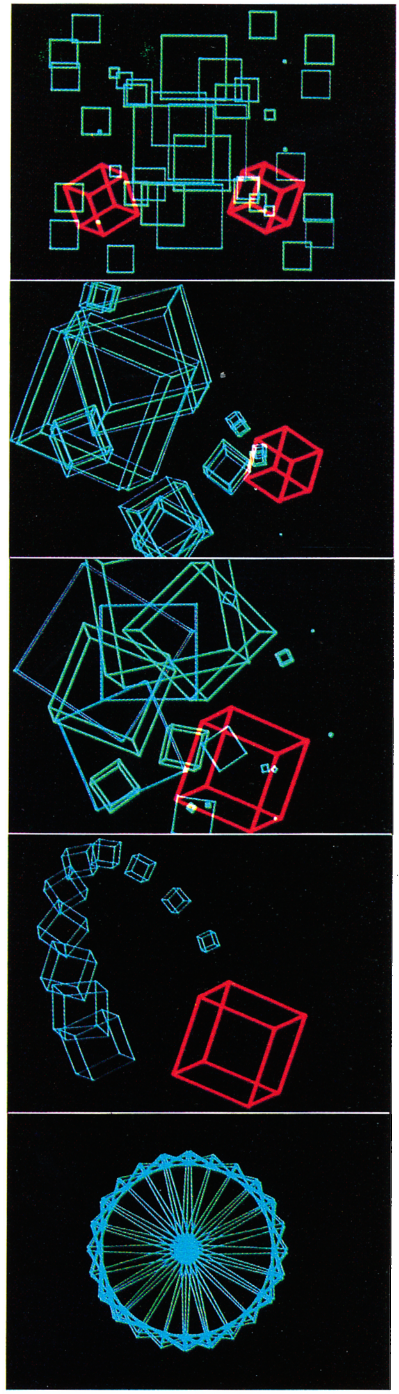


Figure 8

Figure (9) illustrates the result of selecting a hexagon set that moves around a horizontal "figure eight" matrix pathway which was determined by selecting appropriate values of "RD" and "TD." The juxtaposition of this variety of hexagons of different sizes led to a dynamic condition of three-dimensional ambiguity. The hexagon group gives the illusion of being a group of cubes. This was an unpredictable consequence. It is typical of the fertility of pattern which I found in my earliest studies in this graphic domain. *(Matrix III)* Figure (10) is one set of patterns produced by selecting a circle as the basic element. Figure (11) is another selection of different circle dimensions.

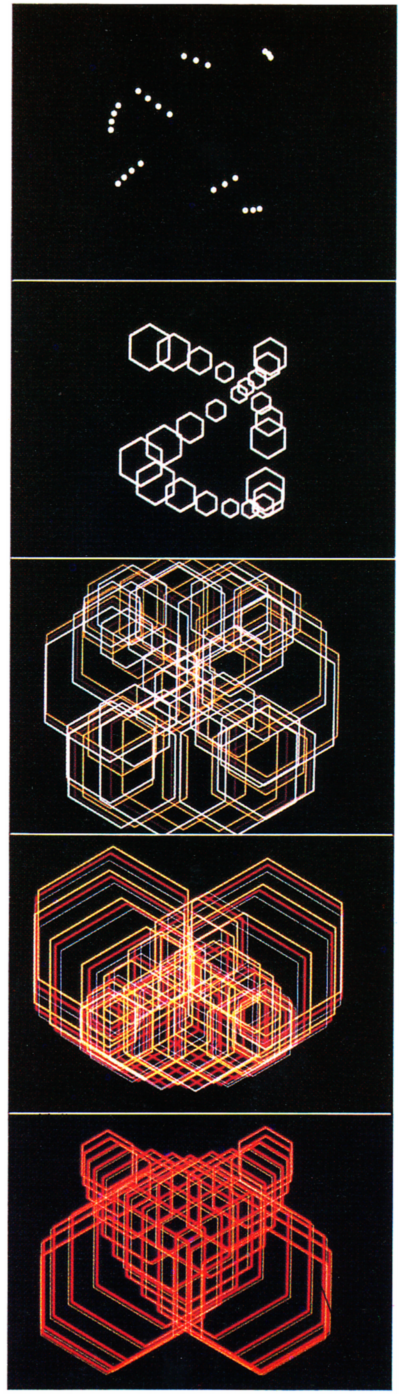


Figure 9

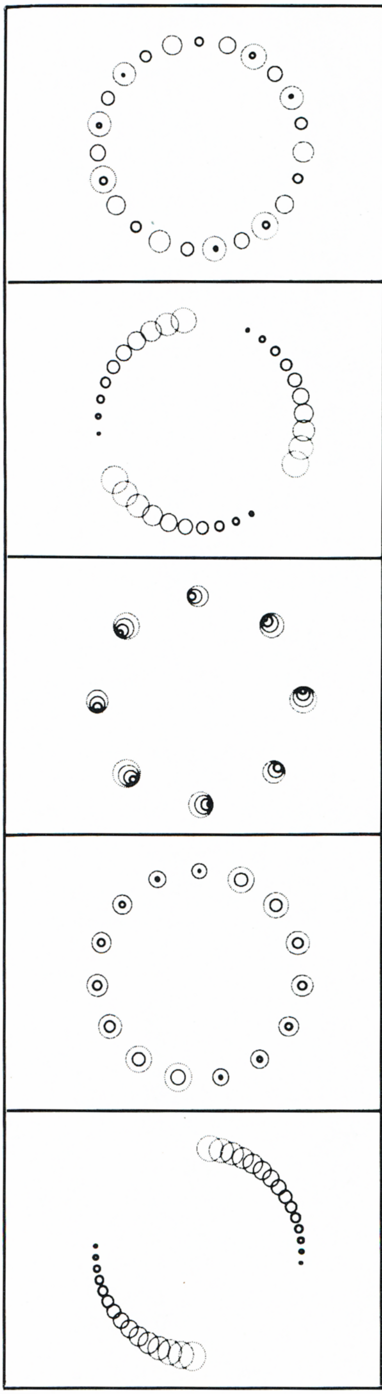


Figure 10

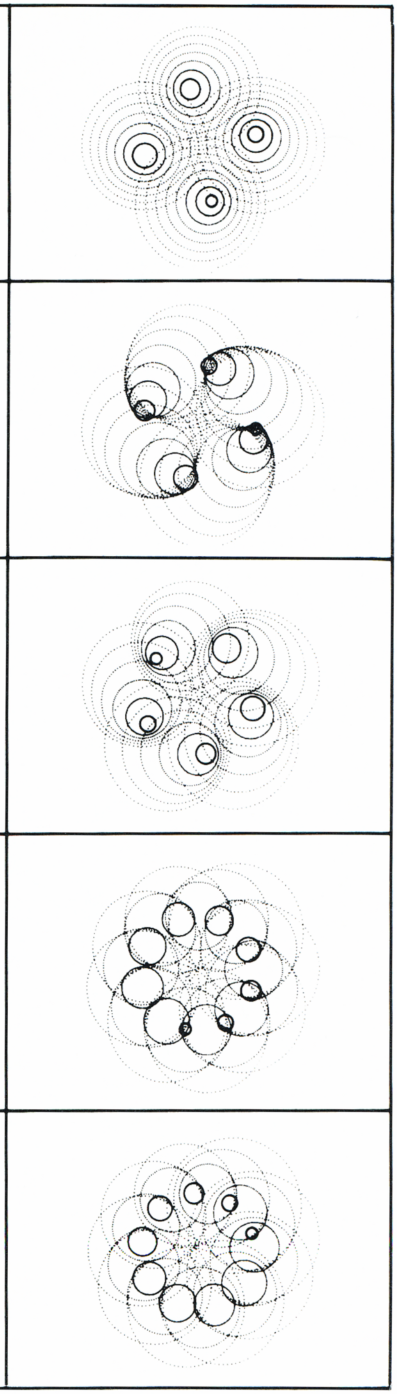


Figure 11

Figure (12)* is included to illustrate future probability. With computer graphic parameters set at forty times higher resolution, the quality of image detail is vastly enhanced. Each sphere is centered where a point of light might have been had we used any one of the many frame patterns of Figures (3) (4) or (5). Pictured in white in the lower right-hand corner is the original dot pattern. In the color illustration, that pattern is rotated about forty-five degrees in space and each of its six lobes are rotated on their own separate axes as if this were a ship's propeller. Each sphere could require approximately a hundredfold increase in the computations needed to generate the original dot pattern. This will be a trivial refinement of future capability.

Differential graphic processes can be specified within exact time constraints. Any real-number step or integer step of the parameters "RD" or "TD," can be set exactly within any measure of time. Any acceleration or diminution of rates can be fitted exactly. Because time is a function of the 24-frame rate of film or 30-frames of video, meter and rhythm are set by a real-number value divided by the required number of integer steps (frames) of the projection media. Any motion can be set to synchronize with another that is set to complete its own action exactly within the time-span of perhaps a third action. This is a method to compose polyphony, the coincident play of two or more actions at the same time.

In summary, we have reviewed, with examples, the functional potential of differential dynamics in visual art. I have suggested that this clumsy and temporary term is analogous to the term harmony – for we are dealing with motion and its emotional or tensional dynamics within both areas. Difference in motion pattern is sensed in terms of ratio, and the simple, **whole number ratios** affect, most clearly, order/disorder dynamics.

Whole number ratios are recognizable to the composer by the more familiar terms: octave, fifth, fourth, major and minor thirds. But they should be, and I think they are about to be, recognized as functional facts of both aural and visual arts. If this is true, this chapter becomes its own homage to Pythagoras.

*See the reference to this in Chapter XI, p. 126.

Figure 12
Digital Scene Simulation by
Information International, Inc.

Chapter VII

The Idea of a Scale in Music and in Visual Art

The ear responds to sound frequencies from roughly twenty cycles to twenty thousand cycles. This continuous spectrum in nature favors no one pitch over another and most sounds on earth are disorderly mixtures of many many pitches sounding at once. The single frequency sine tone is an anomaly. Even the numerous musical instruments that have ornamented most cultures throughout history are not capable of sounding a single pitch. They normally sound various combinations and intensities of the natural overtones associated with each instruments's tonal propagation method. Even so, musical scales around the world consist of precise sets of tones which signify discrete pitch values.

Moreover, the pitch groups of these scales are characterized by their interrelationships. Of course, a scale is a scale only by virtue of these relations. The relations are in fact ratios which transform the aural continuum into something else – a family of ratios (octave, fifth, fourth *etc.*).

From the primordial continuum, then, music is born by fixing steps of exact pitch values (a sure sign of human intervention upon the natural world). Various steps will do, it would seem. We may assume that the music preceded the codification of the scale. Yet many scales have been cherished by a succession of generations, and orderly cultures reflect the great value of this continuity.

Fixing upon some sort of scale happens consistently when making music. Why? For one thing, observe the motion implied within musical terminology. "Continuum" reflects the idea of "continuing," "uninterrupted" in some dimension. We "fix" in order to stop the drift of a set of "steps" that define a scale. There are numerous other examples.

More to the point, as seen in previous chapters, the intervalic relationships fixed by scales are the dynamic structure of musical composition. "Music is motion... tonal motion... chordal motion."* Fixing a scale, then, suggests fixating, in an otherwise too fluid medium, a kind of stepping-stone pathway of exact ratios upon the void, a pattern of orderly steps. The ratios themselves constitute an all important instrument for order. This order may be extremely elaborate in function, involving cross-referent interlocking relationships that rival Chinese puzzles or the subtle world of mathematics. For example, the interval of the fifth forms a fourth interval with the octave above and, with cross-reflectant symmetry, the lower fourth forms an upper fifth in the same octave.

Scale is the ideal instrumentality to cope with the problems of a medium which otherwise would be too fluid. A scale with its surrounding rules of usage, may allow for many deviations from its own specificity, and many do. Indeed, many traditions have "wild card" exceptions to the rules which simultaneously promote order and variety by the simple idea of a rule for liberalizing or "bending" the other rules.

Everyone enjoys the lively motion of music; in the final analysis, that is all there is to music. But, for the composer, that multi-voiced fluidity presents an inexhaustible and confounding range of choice. So the musical scale of intervalic ratio is the oldest way to weave a web of voices into "harmony." Music is probably the most liquid art and the oldest. A cave painter may have marked the stones at Lascaux while he sang to himself a very old song his mother taught him. The song is lost but the painting is still visible on the cave's stone walls, suggesting that art, if not as old as music, is more durable.

Painting with cathode beams is not that durable. Color phosphors are more fluid and more ephemeral than a song. Often, on a color video display, they are liquid as fire and as uncontrolled. How does one cope with these fiery color phosphors that rage magnificently from any mistuned TV? At present, they are subdued into pastel stupor, as with most video art, or otherwise the phosphors churn on as a kind of aleatory art of quixotic mistunement.

That the phosphors either rage or quash into bland pastel stupor

*Zuckerkandl, *Sound and Symbol,* p. 109.

signifies something about a medium that is uncontrolled, out of hand. Often this sumptuous color and activity adds up to a mere manic upper or downer. Little wonder the color video tube was an early item of the drug faddist's paraphernalia. The tube is just too fluid to control with less than a strong mechanism of order. Indeed this video reminds one of the primordial oneness, out of which the musical scales were formed – the fiery primal energy at the birth of form. Even its formlessness is spectacular.

Music making is an act of high precision and accuracy. Tuning strings or piano or timpani calls for adjustments of barely measurable micro tensions. The resultant complex of polyphonic patterns produced by a large orchestra dramatize such preciseness, being a web of many musical configurations playing at once in exact interrelationship. "Video music" fails to match that drama, because most video pattern today contains within its phosphor field obvious gratuitous relations that are imprecise, uncontrolled and accidental. Despite many elements moving at once in various directions upon the video screen, the pattern is not what it may presume to be. Video's inexact "impressionism" is not an equivalent to musical counterpoint by any stretch of imagination.

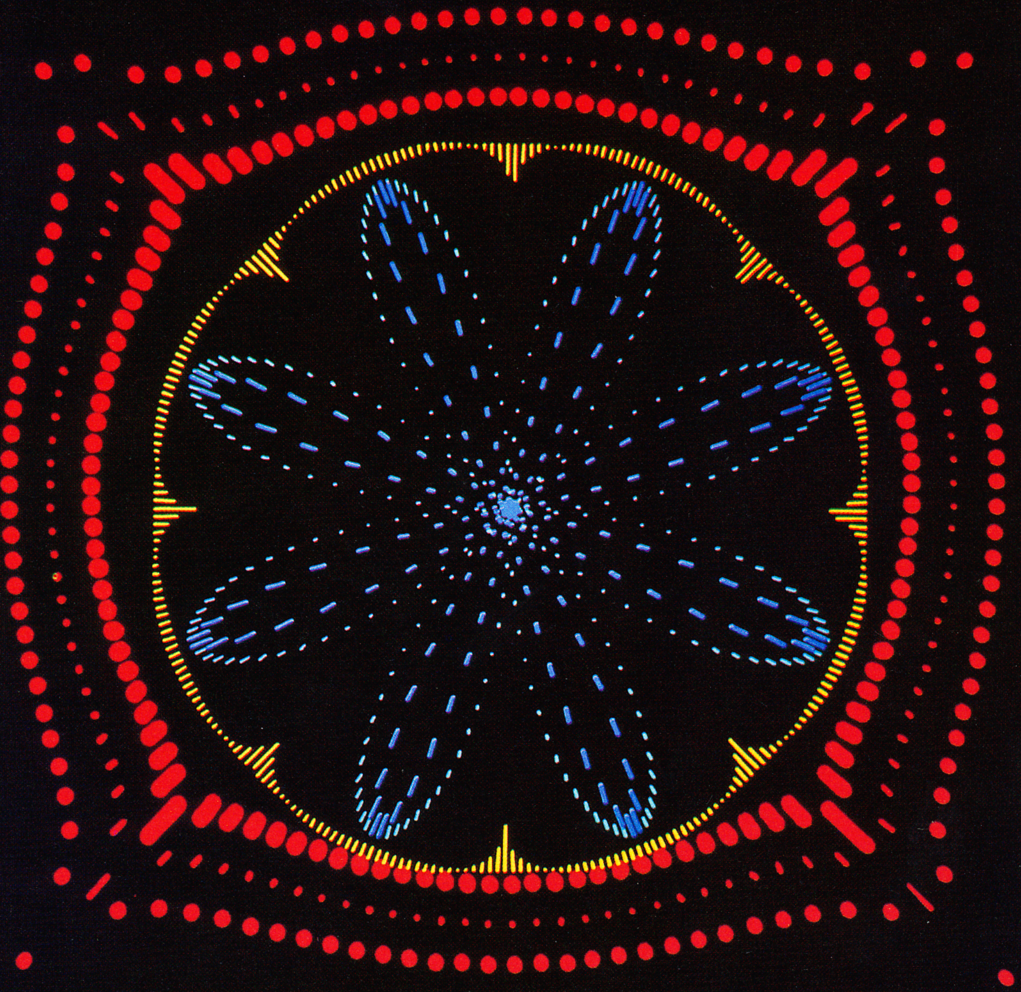
Yet certain overplayed selections from the compositions of Claude Debussy have been used to accompany examples of this subdued or confused video art. Music adds style, credibility and respectability to that image so that it can be used on public broadcast stations to fill time.

What a blunder – this effort to combine sentiments of the "hearth fire" with music. Concomitant emotions of tension reflect the genius of Debussy's music. Any doubt about this would be dispelled by merely watching the care and attention that is required of an orchestra of professional craftsmen in the performance of Debussy's poems. Why display limp visuals, however "colorful," alongside Debussy? Certainly not to fill time.

TV time may pass, but these bland video actions do not shape time. Yet imparting lucid **shape** to time is characteristic of music. Using the chromatic scale to concatenate tonal reflections upon tonal statement – at the exact, right time – that is how Debussy, like so many other composers, gave elegance to the shape of time. Debussy's epitomic good taste, set against visuals that are both pretense and ostentation, generate a

painful mix of irreconcilables. Video shapelessness will not mix with Debussy's fluorescence if only because of the disparity in degree of control of the two media. More than that, there is a clash of quality and attitude. Debussy resides at the pinnacle of a grand epoch. The "art" of video color phosphors really has yet to begin.

That beginning begins with setting a scale to the multidimensional color field of video's charged phosphors. I would hope that Chapters V and VI have provided a hint that a scale **can** be laid out upon this rich continuum which holds the very highest potential for design. The history of the plurality of musical scales as sketched above should serve to remind one of the redundancies of culture. There likely will be many beginnings until this art of video becomes the mature co-equal of music, equal to Debussy's style and invention, or the music of earlier centuries.



Chapter VIII

The Role of Color and The Role of Music

In his book, *Interaction of Color,* Josef Albers asks us to compare, as an example, the four notes of the "Good Morning To You" Kinder song, to four related color intervals.* Whether sung by child or adult, whistled or played on an instrument, a melody retains its own character. Yet the intervals of color relationships are difficult to retain even transposed a mere shade higher or lower in key. Albers acknowledges how comparisons of this sort can be informative, but just as often, they are misleading.

"Tones appear placed and directed predominantly in time from **before** to **now** to **later**. (my emphasis)... Colors appear connected predominantly in space. Therefore, as constellations they can be seen in any direction and at any speed. And as they remain, we can return to them repeatedly and in many ways."○

Other writers reflect upon the similarities as well as the differences between musical and color triads, noting the separate ways in which tones and colors mix. While sounds seem to retain independent identity, colors do not. Paul Klee and many others gave particular attention to the implied dynamics of colors. All agree that most color relationships present a dynamic thrust toward or away from one color to another.

What if we cease all these considerations of color as pigment and put aside Albers's New England fall colors? If instead we turn to observe the transient color phosphors of the video picture tube, many of the contrast-

*(New Haven, 1971), p. 34.
○ *Interaction*, p. 39.

ing characteristics of those examples of tone and color will no longer hold true. The video phosphors can be as ephemeral and transient as tones. Yet most studied and recorded differences between color and tone are related to the perception of static color versus the transient nature of tone. What happens when these differences no longer prevail?

Upon a second look at video phosphors we seem to have landed upon a new continent of exotic perceptions. There is no hint how these colors will be perceived. There might be a way to liken dynamic color to music, but no one knows about that even though tones and colors have undergone separate and joint perceptual scrutiny for a century or more.

Even so, like any new world, this region of color experience in temporal flux has been an object of the imagination and even a few preliminary explorations. No need to recall a painful history to sense the irony that after centuries of failed color organ inventions, at last a workable color organ resides in every home with a color TV. It only awaits its own software; the hardware has arrived.

On a continent where color presents itself as "from before to now to later," the **transiency** of color lies open to exploration. I confess my own puzzlement despite nearly forty years of color filmmaking. During all those years it seemed that the methods used to produce transient color were the least under control and least understood. In spite of sophisticated color film technology, which underwent a revolution itself in that time span, I wondered if color control would not change again radically with the introduction of dynamic video color. Now I know for certain that it has changed, although phosphor video color dynamics is not yet fully consolidated under technical or aesthetic control.

One propounds theories for the use and effect of color; I made a new plan with each film. Rarely have the best ideas lived up to expectations. Color for the painter is normally an intuitive experience of direct one-to-one interaction between three components – pigment, hand and eye. These intimate hands-on interactions call upon a part of the creative mind other than the reasoning channels needed to work creatively with color film. My effort to achieve painterly control of color film processes were too often frustrated. Lab and printing stages interpose processing time as a kind of insulation between the intuition of the moment and the actual color effect.

Video color surely will allow an intimate one-to-one control of color change. Soon, full control of the profound experience of color in dynamic transformations will become a visual tensional force and an instrumentality of art.

A time will come when color, less a subject of static contemplation as in painting today, will be more a force of dynamic expressive power. At that time, color's active association with music is bound to become a lively issue. Just as the composer calls upon the full repertoire of musical instruments employing each one, or each combination, for its timbre, its "coloration," so he will select from the repertoire of phosphor colors for similar dynamics.

Over many generations, the idea of this visual dynamism has dwelt in so many minds that I wonder if it does not rival the dream of man's aspiration to flight. That dream was to fly above the earth, departing from stasis and weight. The dream of visual dynamism is the same: to leave behind earthbound stasis and, in the mind's eye, personally or vicariously, to "fly" in that liquid space of musical architecture without inertia or gravity – but with that elusive "musical" attribute of color.

Bound for Rotterdam, I tried to film that liquid vision on shipboard. Dream, myth or youthful fantasy aside, color and tone have an assured future together in that very space.

After these millennia, music may be **too** well explored, with its grand excursions in that domain of fluid architectonic fantasy. I contemplated with misgivings the discrepancy between the very old – music – and the very new – electro-optics. Wondering how such disparate coupling could ever be reconciled, I speculated upon the idea of starting afresh within my vision of optical/aural complementarity.

This reflection may make sense: if, as noted in the foreword of this book, twentieth-century music is in crisis, here is a way (if a somewhat chastened way) beyond the so-called creative exhaustion of classical meter and harmony. One can foresee a fresh start for music with a fresh graphic partner as one-to-one architectonic co-equals in this newly discovered wonderland of digital harmonies.

I was never fully content with the relations of my own films and their sound. I saw in every sound track a form of compromise and each presented a dilemma. Many viewers sense an incompatibility here and

argue for no sound at all. Yet another argument is noteworthy. The eye, as a witness to events in nature, expects a matching sound with each event. Why should a visual experience, so close to music as these films, happen in silence? We think of dance or opera as a matter of course.

On the other hand, apart from the obvious traditions that music and painting are both wholly self-sufficient, why **not** a musical experience to be shared with, and equally involving, the eye? Why not visual color patterns which are so constructed as to weave with aural patterns in a fruitful complementarity of architecture? The interrelationship might be as elaborate and the consort as true as violin and piano which discourse in the typical partnerships of all duo or multi-voiced compositions. This would be a partnership that is valid only if the combinations produce interest greater than the separate contribution of either the aural or the visual member.

Here, many will argue that this is exactly the objective, often achieved, in the relationship of music with dance. Yet the complementarity in my vision would **begin** at the very limits of the ideal of dance joined with music and proceed from there. For that ideal is instantly exceeded, simply because of inertia and gravity. The body has more – and the cathode beam has less – size and mass than the sound of a flute.

With real enjoyment, I recall working with my brother on a few of our earliest films.* These presented a one-time exception, within my experience, to the dilemma of matching appropriate action with music. That exception, directly due to our music-making instrument, provided an unequalled opportunity to integrate image and sound. First of all, the musical instrument was as primitive as our animation procedures. Second, and most important, the procedures of frame by frame production were alike for both sound and image. Despite many difficulties, design ideas for image somehow stimulated counterpart sound ideas, and in turn sound pattern was literally mirrored, figure for figure, in an image/sound dialog.

It will be useful to look at details of these early experimental film making processes.○ Our homemade sound track device consisted of an

*See James and John Whitney's films *Five Abstract Film Exercises* (1941–4).

○ See Appendix, p. 151. Films produced with this equipment won First Prize at the First International Experimental Film Competition, Belgium, 1949.

array of pendulums which were tunable by adjusting weights, as are clock pendulums. The quality of sound produced by this primitive instrument, which makes no sound of itself (its frequencies are sub-sonic), compares with the early electronic music produced after the introduction of general music synthesis a few years later.

The pendulum device produced, silently and ever so slowly, a conventional optical sound pattern on the motion picture film by virtue of the mechanical action of swinging pendulums. In other words, the waveform patterns of musical events are drawn out in time by a factor of a hundredfold magnification. Playing a musical "motif" is done by starting and stopping each pendulum at its right moment as marked on the score. It could take more than sixteen minutes to record ten seconds of sound track. Then, these sound patterns on the film must be developed and played on a conventional sound projector to hear, for the first time, the motif.

Ever so slowly, music is made, wave for wave, by the swing of a full scale of pendulums. So slowly, in fact, that each minute interval of time, never before accessible to composer or musician, can be composed and structured. Exceedingly brief clusters of tones simply can be played out by starting and stopping the pendulums, sixty or eighty or more successive pendulums sounding within the hundred seconds it takes to record one second of a composition. Of necessity, we differentiate between rhythm and timbre for obvious reasons, but both are the same if time is viewed at these hundredfold expansions.

More to the point of this digression, the instrument served as a model for conceptualization. As with my experience with counting gear teeth as a model of geometry by means of my mechanical analog precursors of today's computer, so this mechanical music machine drew my mind into speculation upon digital music instruments. In my opinion, our pendulums in the early 1940s and the music we composed presented more that was relevant to the musical issues of our time than the tape splicing technology of the electronic music of the 1950s.

Intuition informed me that the very mechanical (homemade) sloppiness of pendulum linkage to light-valve in our sound recorder (in itself a novel transient waveform generator) was a significant factor in tonal quality. It suggested that the source of the timbre (sound quality) and the

appeal of the traditional, still unsurpassed, handmade musical instruments results from inharmonic, transient waveforms, which are exceedingly varied and brief. We produced similar inharmonic transients by starting one pendulum and allowing it to swing perhaps only four cycles, then starting another as the first was stopped, then starting a third, say, after the second's twelfth cycle. Thus, patterns of microclusters were composed in the domain of rhythm. Yet in their transience their net (playback) effect produced timbres in the composition being performed. We were more than pleased with these sound qualities; we were amazed.

In general terms, the lessons from these experiences suggest to me that there are benefits to composing pattern from the smallest element outward, from the center and not from the fringe, both for optical and aural composition. Nowadays, opposing points of view of **synthesis** *vs.* **analysis** are associated with opposing attitudes on the creation of both electronic image and music. The television camera (and the movie camera before it) records a given gestalt, so to speak. Editing – choosing subject, "camera angle" and sequence of scene to scene – is a process of *analysis*. Improvisation – the improvised performance in real time with any musical instrument, video or audio synthesizer (both confusingly misnamed) – is a process of *analysis*.

On the other hand, creating graphic action or the music out of the blank nothingness, as in my computer-generated procedures, would seem to represent the *synthesis* process. By the same consideration, writing music note for note at the manuscript is also a process of *synthesis*. I favor the *synthesis* approach to composition, more or less, over trends of experimentation around the world. My position is one that may run contrary to the many individuals and institutions oriented to real time performance upon audio and video "synthesis" machines through improvisation.

Our films of the early forties, composed on a pair of handmade machines, one for picture and one for sound, are "homespun" at best. But it is doubtful if, to this day, many other films possess a similar tightly drawn structural interrelatedness of their sound and image parts. Those films are one example, albeit ever so primitive, of exact complementarity between the architecture of the sound and the picture.

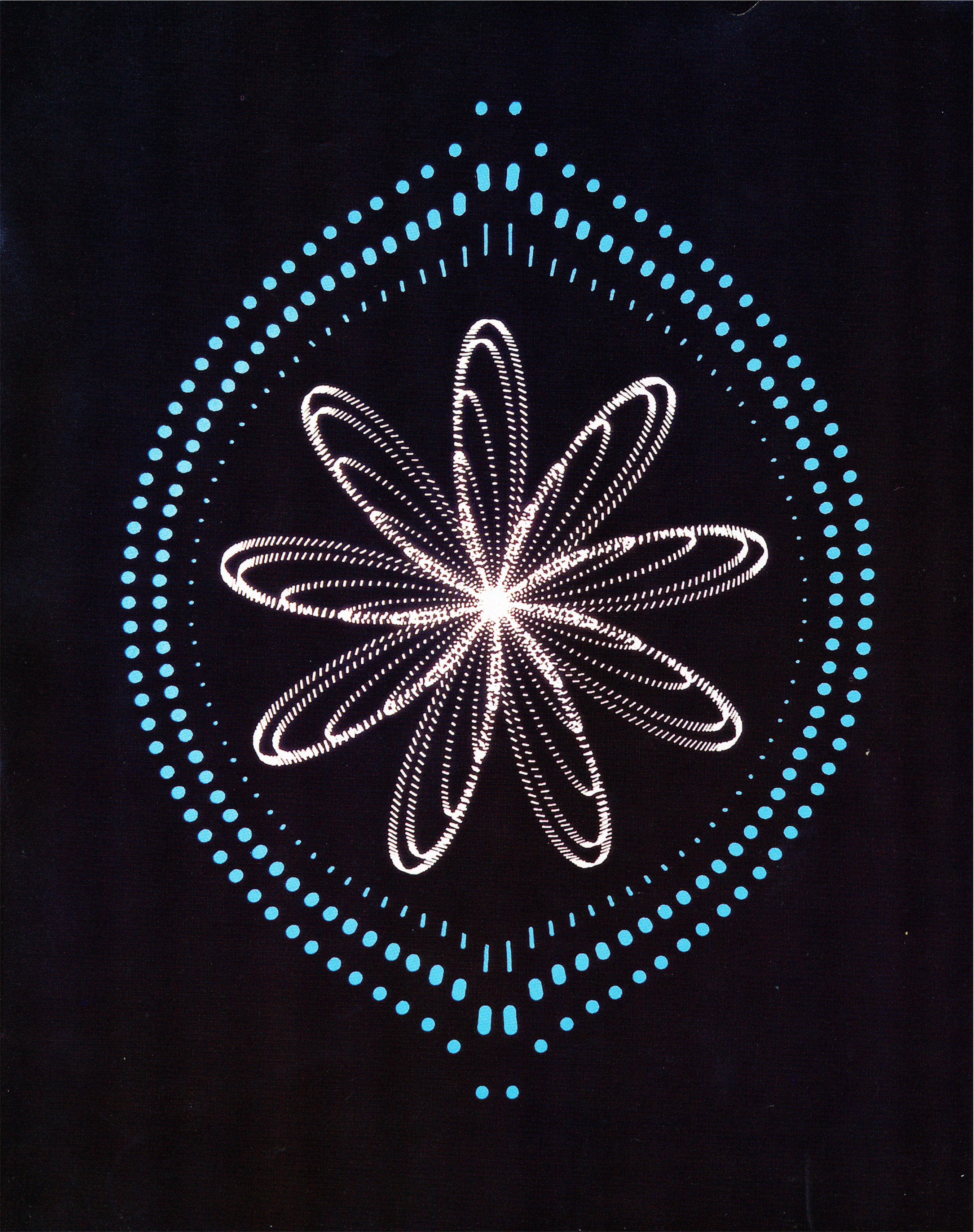
This earliest practical experience with complementarity, however

primitive, still lives clearly in my memory, and because of it I believe fully in the prospect – near at hand – that sound and image composed on the same digital instrument will have totally revolutionary consequences. In a technological aural/visual universe, music must become bisensory. Of course I do not mean music must always be bisensory.

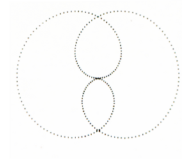
I have not composed much digitally integrated sound with image. Nor have many others. My computer facility for digital music is still evolving and at this time, no instrumentation permits full dynamic manipulation of color. As to both prospects, it is clear that in the future there will be practical instrumentation for both digital music composition and controlled color image. Indeed this is the wave of the future which is due in this decade.

The following chapter will offer a description of the film, *Arabesque*. Composers may wish to compare how close, or distant, graphic problems of composition approach their own. The film is perhaps a meditation upon the concept of aural/visual complementarity. It is also an example of synthesis – a work from "the center not from the fringe."* Still, *Arabesque* is a compromise. Its digitally composed image is not matched with digitally composed music. Its sound, however appropriate, is as severe a compromise as any others I accepted reluctantly upon this long road toward the goal of free composition with instrumentation allowing perfected digital access to image and sound through digital harmony.

*Alan Watts, in his "Introduction" to Al Huang, *Embrace Tiger, Return to Mountain* (Moab, Utah, 1973).



Chapter IX



Arabesque – An Analysis

Opening Section:

The generative design for the entire structure of *Arabesque* is an array of 360 points distributed around a circle. These points are numbered 1 to 360 and they move according to the differential rule of number value that moves all 360 points in one direction, horizontally to the right, each point at its own differential rate in value steps from 1 to 360. Point #1 is located at the bottom of the circle. It is the first point on the right of the vertical diametric axis of the circle. The point numbers increase 1, 2, 3, to 360, counterclockwise around the circle. Point #360 lies next to #1, on the left of the vertical axis, at the bottom.

The illustration, p. 98, Figure (13) presents a selection of frames of the basic action from which the entire film was made.* This action is complicated because of the modulo rule change at the frame edge. As any point reaches the right-hand edge of the field, its X coordinate value automatically drops to 0 by a modulo function of the computer program. This causes that point to jump to the left field edge where it continues to progress to the right as before. The seventh, eighth and ninth frames of Figure (13) show steps in the progress of the modulo jump to the left.

The selected frames in Figure (14) present more detail of the overall design of the film. Because this represents the generative fountainhead of the entire film, it will be informative to describe all of these frames in detail.

Differential rightward motion rules all of the 360 points throughout

*See Chapter XII, for listing and description of Pascal program.

the entire film. A complete cycle of differential action can be calculated to be 360 cycles of the fastest point. This is required to complete 1 cycle of the slowest point. The first 360th of one whole cycle is completed in the steps shown in Figure (13). Point #360 has moved one full cycle when it meets point #1 at bottom, center in the ninth frame. That first complete cycle of the fastest point has been completed at the second frame of the illustration, Figure (14). The second cycle is shown in the third frame and the third cycle, or the third 360th fraction, is shown in the fourth frame. The fifth, sixth, seventh cycles follow. The last frame of this illustration is not the eighth but the 90th cycle, or the simple whole number fraction, the first quarter or one fourth of the whole cycle.

Arabesque begins with the circle of 360 points arrayed as noted. The action moves rightward to the first 360th cycle step. At this point, cyclical action ceases and another action begins – a polarity switch, an inversion or reversal. One well-known coordinate feature of computer graphic displays allows the image to be mirrored or inverted by a simple switch of the polarity of either the X or Y coordinate values. This is also expressed as an inversion of coordinate values. After the opening action advances its one cycle step, the action now changes smoothly to a reversing action of the horizontal polarity values. At the completion of one full polarity switch, the forward action smoothly resumes to make one more cyclical advance. Then, at the end of the second 360th cycle step, once again polarity values are switched. This time it is the Y coordinate value that will be changed progressively to negative. See Figure (15).

These alternating cyclical motions, interrupted

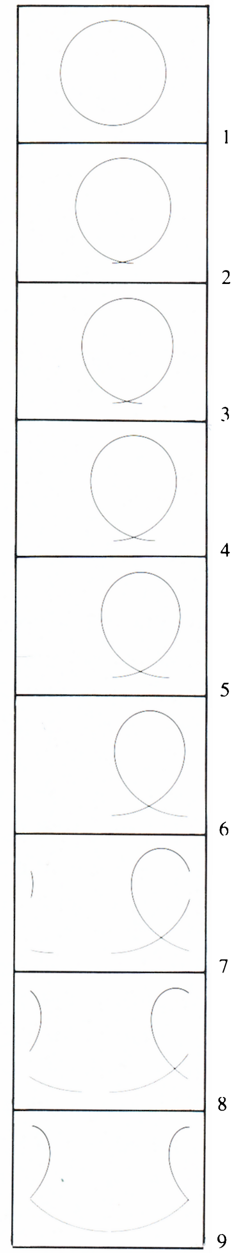
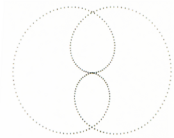


Figure 13

for polarity switches, create an interesting and hesitating pattern of motion which resembles somewhat a very slow and stately dance. Composers are familiar with musical structures that alternately advance, then seem to dwell a beat or two, and then continue. In the film, this quality of action is an alternation between forward motion and symmetrical motion. The cyclical advance moves consistently to the right. This forward movement changes to the symmetrical motion, the axis of which is alternately horizontal or vertical. Then a resumption of the forward, rightward motion follows.

In the film's opening sequence, at the middle of the second symmetrical action, the curved triangular image has been squeezed down to no more than a horizontal line located at mid-frame. This reduction to a line occurs at the point when the Y coordinate reaches zero between Y+ and Y−. At this point of the action a substituion is made for another copy of this same action which is enlarged about 20%. This new sequence is combined with itself. The superimposure is also enlarged to the same size as its partner and it is inverted.

Now both of these new sequences move in reverse. Since the moment of that substitution coincides, all three – the one dropping out and the two that commence here – effect a kind of magical event. I call it **magic** because this act of substitution is smooth and practically invisible (all three elements momentarily appear to be merely one horizontal line). It is all the more magical because it is not noticeable that the actions of both have begun a retrogression which takes them back to the circle from which they began. This concludes the opening section of the film. See the color strips, Figure (15).



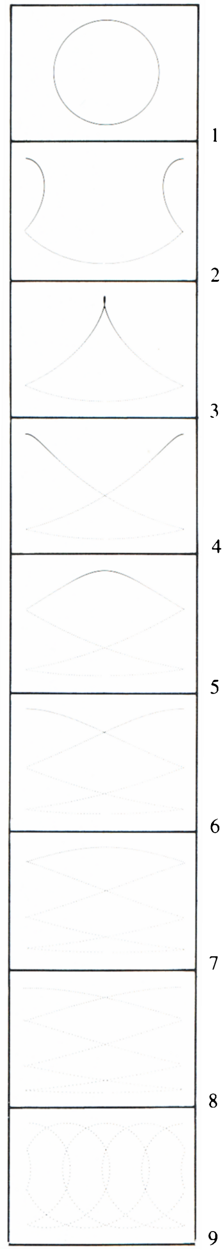


Figure 14

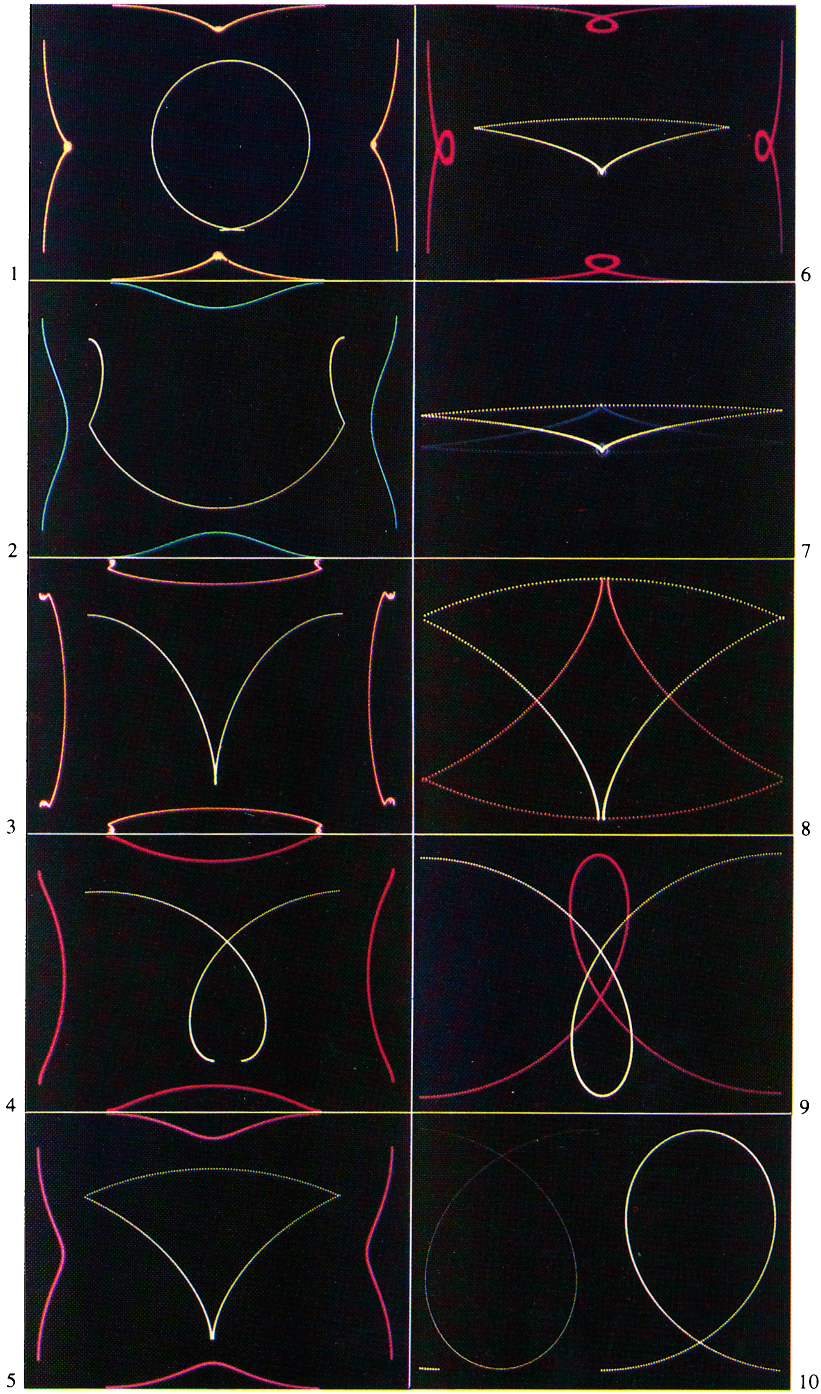
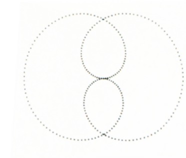


Figure 15



Section Two:
The second section opens with a fade-in of a circle similar to the first section but half the size of the first. Furthermore this circle's #1 point is at the top of the left of its vertical axis. Thus, progress to the right with the rightward moving points, produces a different pattern of circle unfoldment. The motion is faster than before and the action appears to be complete through one full cycle. This is not so. See Figure (16).

Instead, after this circle has progressed approximately a third of the way through its cycle, it is faded out. In fact, this fade-out is a cross-dissolve with another action of a larger horizontally elliptical transformation of the circle. This new elliptical transformation cross-dissolves, or fades-in near the ending of its own cycle. The larger figure decelerates to a stop as it forms into its final elliptic figure. The smaller circle, which began the sequence, fades-in over this action. It is now ready to begin again at the same position from which it started before.

The elaborate cyclical character of this 24-second section, of which there are six repeats, does generate a strident driving rhythm that is at least one level more sophisticated than the film loops of Fernand Léger's *Ballet Mécanique*.* The action may not be as comic or historic, but there is more going on here – more of the kind of organization of forces which gather, rather than disperse, metrical rhythmic pattern. This is what we expect when any driving rhythm is set in motion in any musical work composed over the last four or five hundred years; examples abound in music from Scarlatti, Vivaldi (Seasons) to Stravinsky.

Section Three:
The third section takes up this strident rhythmic pace. After a pause consisting of a slow fade-out of the last horizontal ellipse, there follows an equally deliberate fade-in of an opening vertical ellipse, this being still another variation of the original action. This one starts its #1 point at the top right of the vertical axis so that a third type of action is announced, as shown in Figure (17).

The momentum of the second section is restored by the action of this new ellipse as it moves to the right. It is followed by a second ellipse

*See Chapter VI, p. 72.

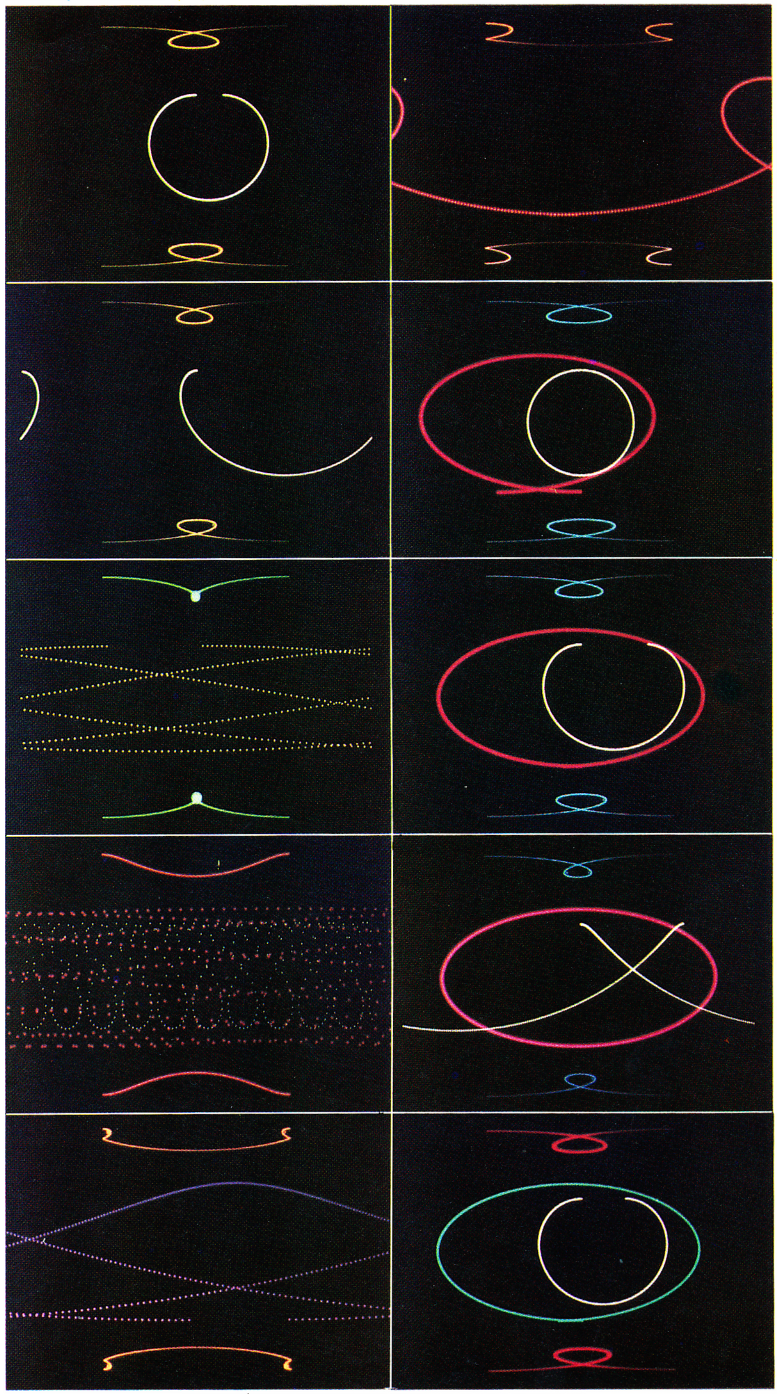


Figure 16

which appears 32 frames later in the same starting position. Then another, and another appear in a canon or rondo type action of repeats and superimpositions until a total of five have started at 32-frame intervals. Each of these fresh starts is in a different color and while centered vertically, the later ones are displaced slightly above or below the horizontal center. See the color strips, frames one to eleven.

The action of run and pause in the first section was caused when the rightward motion was arrested and a symmetrical polar switch was substituted. This is taken up by a similar alternation. These new ellipse actions run through each fifth of their complete cycle at which stage the points form five ellipses that are spaced symmetrically in the field. The five ellipses undergo the same symmetrical polar switch, or reversal, first in X, then in Y, then in X and Y, (causing the five ellipses to shrink to a point and then open back to their original size). Finally, at the fourth of these fraction stages, there is once more an X-axis polar switch. See Figure (17).

More than is usually the case, the illustrations fail to convey so much as a hint of the quality of the motions involved at this point of the film, because a form of "counterpoint" develops at this juncture which can be described better than it can be illustrated with any limited selection of still frames from the motion – a counterpoint of smooth flowing action that resides more or less "within" the driving rightward motion. The two retain their separate identities while neither diminishes the other.

Six different superimposures in different colors are on the screen at once. After the opening moments of this canon, the action has increased in complexity until the smooth symmetrical motions superpose with the rightward driving motions at all times. Yet, each retains its identity. The opening build-up to this is matched by a closing retard, finally dwelling upon the action of the last ellipses that oscillate slowly by means of a series of the same X-axis polar switch. See frames eleven to twenty, Figure (17).

Section Four:

The fourth section is a play with fractions. Like Section Two, it begins with a circle that commences a rightward drive to its third fraction where three circles are arrayed horizontally across the frame. Upon

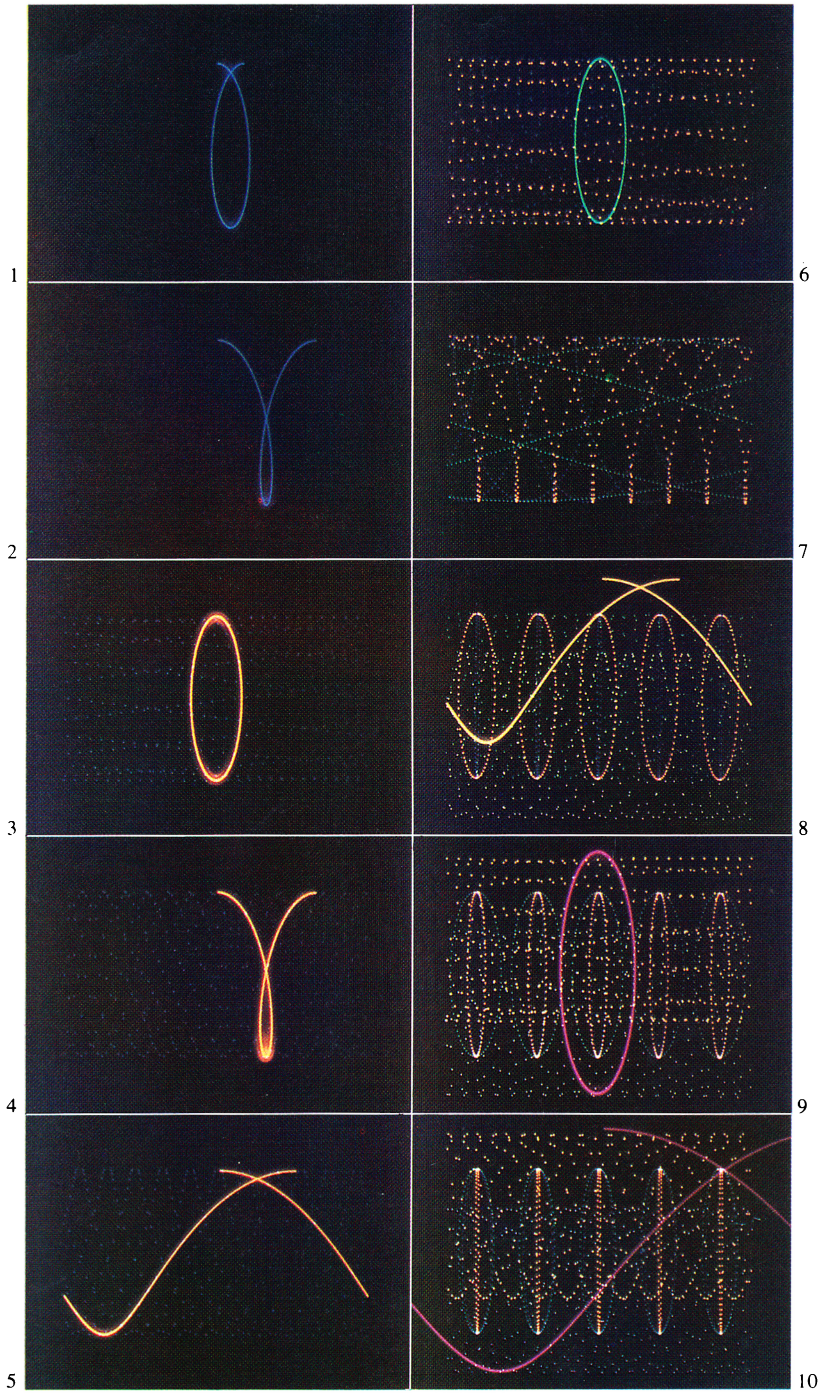
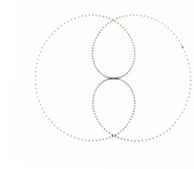
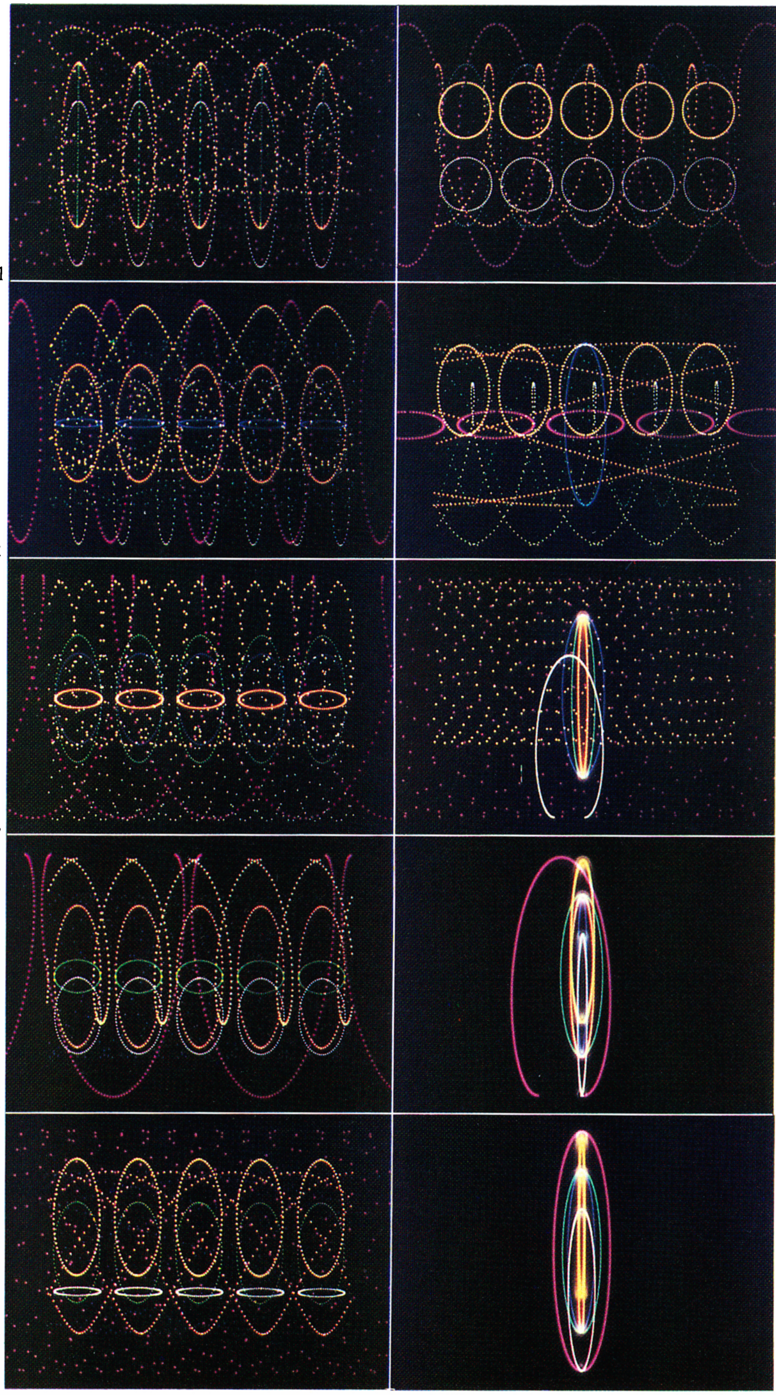


Figure 17





11 12 13 14 15

16 17 18 19 20

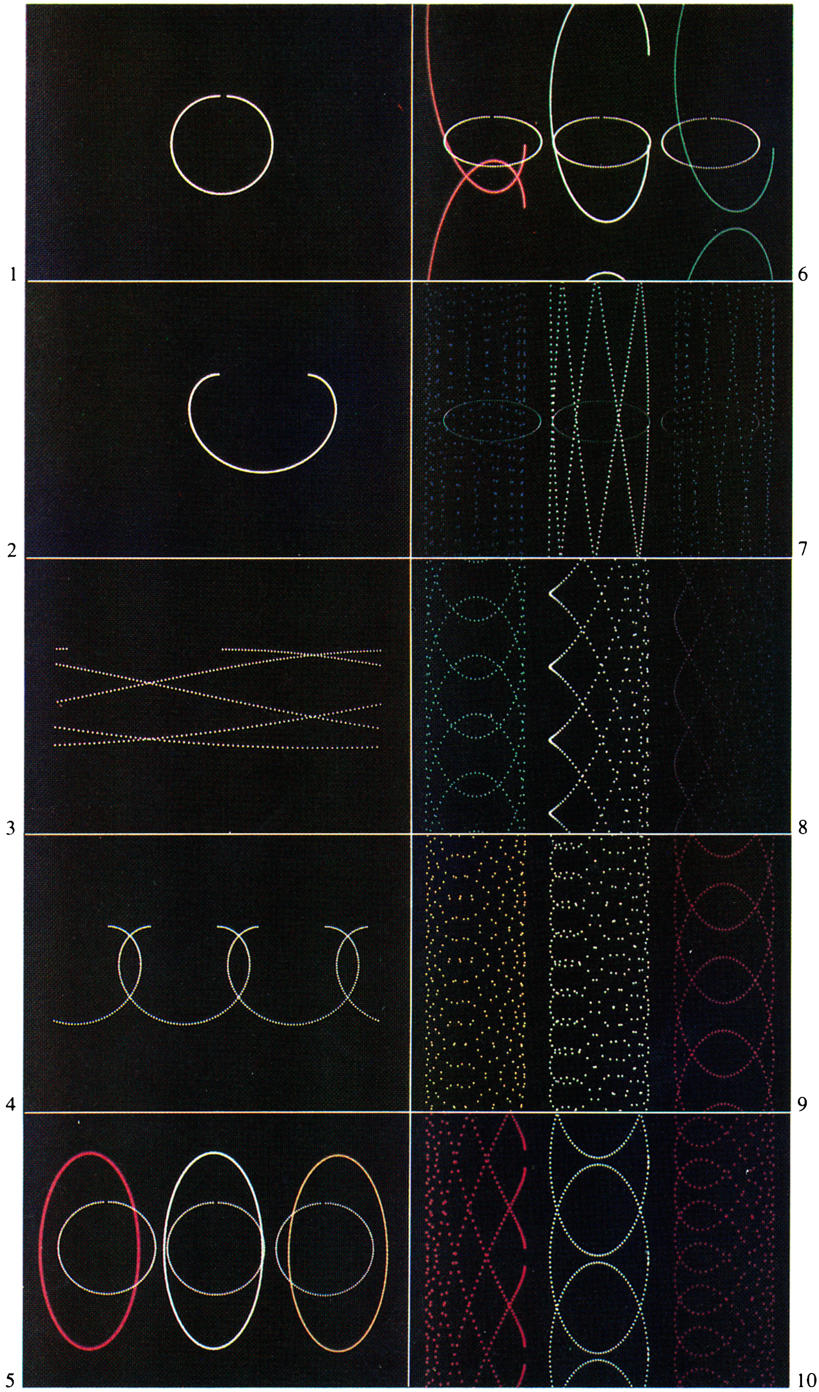
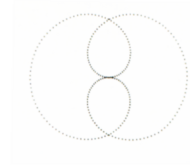


Figure 18



these three circles, three vertical ellipses appear. From these starting positions, each one advances, not rightward as each time before, but upward. In effect these actions have been turned ninety degrees counter-clockwise. All three actions begin simultaneously, but all three actions are timed to a different low-order fraction – namely the third, fourth and fifth fractions. The consequence of this is a changing action pattern across the frame at all times as each vertical, upward moving column slows in turn to its own whole number fractional resolve. See Figure (18).

The first fraction resolve that shows is the fifth, which appears on the left, then the fourth on the right, then the third at center, then the second fifth on the left and the second fourth (which is the one-half fraction resolve). The third fifth is followed now by the second third, the third fourth and final fifth, and at last all three columns resolve to three ellipses. Once again they are superimposed by the same three circles of the opening which advance rightward till this action resolves to the end of a full cycle – at the circle.

This triple play action offers another hint of new ways with optical counterpoint. An arbitrary working out of three fractional sequences hardly constitutes a fugue. But consider the coincidental timing that matches the departure and return of the three vertical actions with the three circle elements of the horizontal action. A more elaborate plan of departures and arrivals and the various patterns of their layout in the optical field could be constructed now. I begin to imagine what it was like to compose the fugues produced in great numbers by the legion of polyphonic composers.

Section Five:
This is an interim section during which various border fragments (more on these later) jump, skip and step, in and out, with a free rhythmic play against an aural percussive accompaniment.

Section Six:
The sixth section presents several examples of various opportunities for optical composition. It begins with a canon based upon the first 360th fraction presented at the beginning of *Arabesque*. This Ω to ∪ action, completed in approximately four seconds, holds while a second action

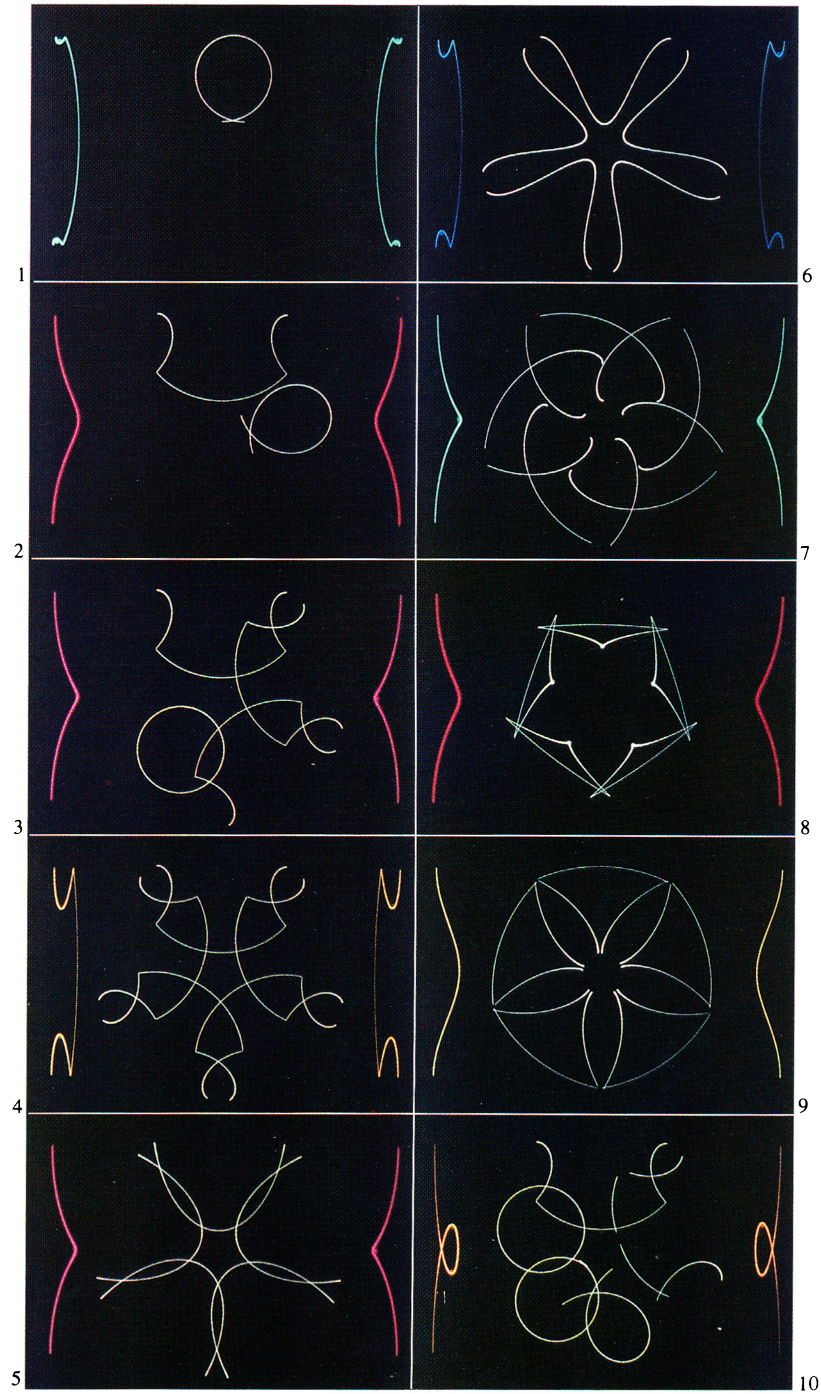


Figure 19

begins, rotated 72 degrees around. Four seconds later a third begins, rotated another 72 degrees. Then another begins and finally the fifth is completed. The five figures have now formed a pentagram of curved linearity – a strong image found in Gothic rose windows of Europe, in turn derived from Islamic figures. See Figure (19).

With the pentagram completed by the fifth repeat of the to action, all five continue in unison through their X-polarity switch, as in the opening section; then the second 360th fraction is completed and halfway into the Y-polarity switch, the retrogression begins as in the opening events. The conclusion is "taken apart" much in the manner by which the starting of this section was "assembled."

Examples of ideas for further study abound here. One should usually avoid assembling elements piece by piece, while each piece, already in place, remains static, waiting for the whole to be completed. Assembling elements that way gathers accumulating stasis. It would seem that this is a valid optical canon, because ways can be found to overcome the static factor. In this section of *Arabesque,* even the aural action is a factor that contributes to minimizing stasis.*

Doubling of voices (repeating an action in unison – however it is transpositioned about the field) should be avoided. Although the pentagram which is produced is an evocative image in motion, still that motion is strongly kaleidoscopic – an avoided term and an avoided effect, most of the time, because the term and the effect are overused. Symmetries generated by kaleidscope or snowflake are not unwelcome. But like medication, overuse quickly becomes overdose. Doubling of voices produces redundancy of motion too. Kaleidoscopics and doublings are both quickly overdone.

Composing this section offered the most difficult choices. It remains temporally dubious – probably the first section where actions begin to drag. Perhaps it is too deliberate, too slow for its place in the total scheme. It is not a miracle of perfect timing, unfortunately.

In this analysis, these paragraphs constitute a cautionary section. Surely, caution should be exercised with the very idea that static parts

*See Chapter VIII. Digital interrelations of aural/visual composition point the way around these problems of design.

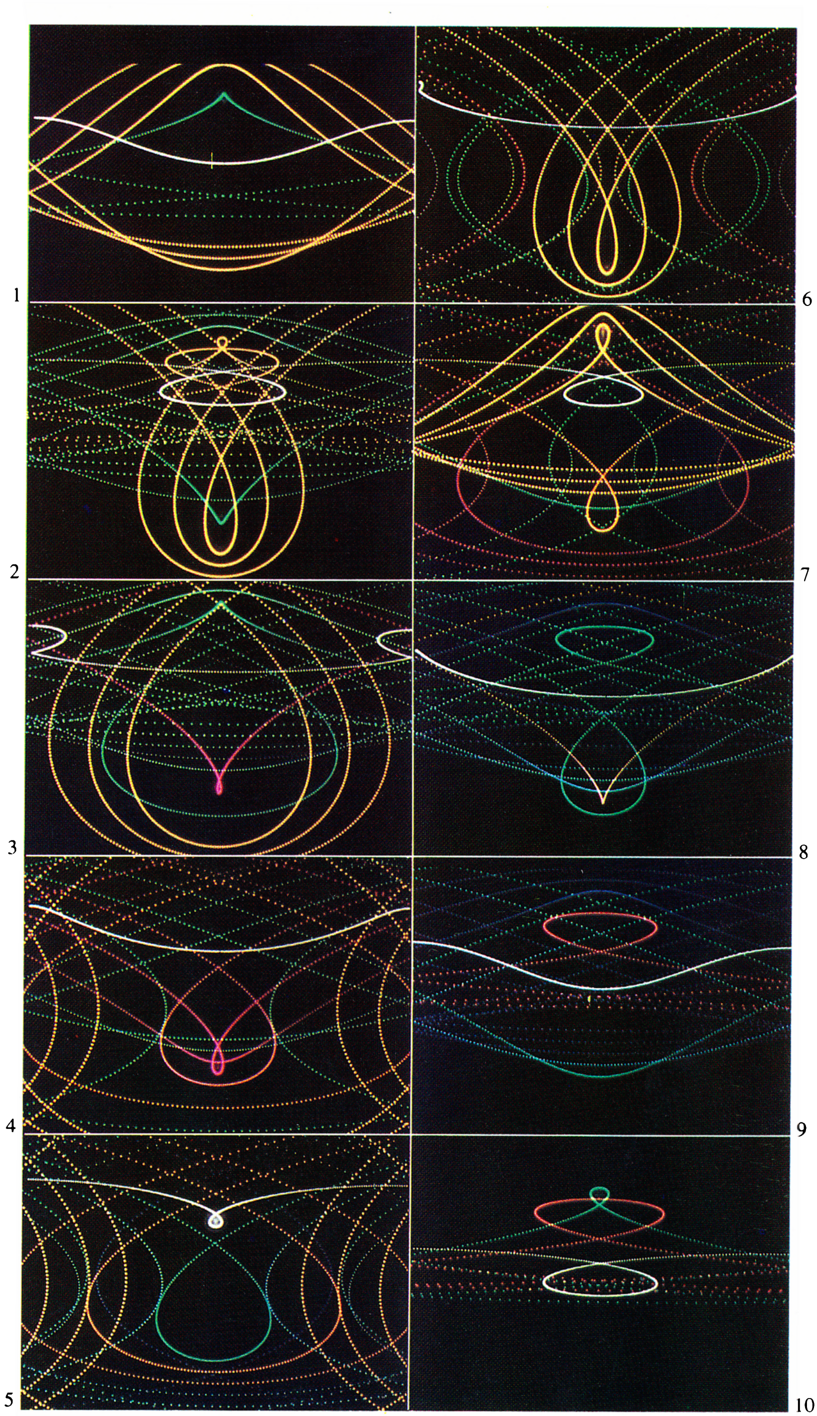


Figure 20

can be built into a canonical structure. The goal of action cannot ever be a static image. Why sit still for the tedious procedure of composing optical stasis? This violates the primary logic of the idea that "motion molds time." All of art history spans the age of timeless, permanent art. We are accustomed to expect visual stasis. On the other hand, art in motion is an uncommon idea that must be cultivated. It is best, for now, to discover, then count, the ways motion molds time.

Section Seven:
Arabesque's final section is a play upon symmetrical action which is derived from switching horizontal polarity values. Several new full-field variations of this recurring action are played in canon against themselves. They produce a rich texture of color and action as a fanfare conclusion with appropriate sound. See Figure (20).

It might be expected that the driving action of earlier sections would belong here. But this time more symmetrical action with more scale and breadth of dynamics provides the bombast of a cadenza while its symmetry retains a sense of resolution that is called for here as an ending. The early rightward drive carried the action forward, onward and upward. Now this symmetry, which at its peak is as forceful as the driving rhythms, produces actions that summarize without introducing new ideas. Finally the symmetrical action is allowed to dwindle away in a quiet resolution.

A few graphic details remain to be described. First, the same switch of polarity used throughout this composition has still another application as a rhythmic framing instrument such as the percussion instruments of an orchestra. The line drawn by the action at the first 360th fraction is an inverted loop; . Its Y-axis is reduced and its X-axis is extended, then the action is cut at a certain point so that a loop is created which repeats as an unchanging rhythmic pattern.

This loop, too, is hardly different from Léger's washerwoman. Critics have reminded me many times of this, objecting to the "jump-cut" in what is otherwise a smooth action. I respond that the jump adds a percussive slapstick snap to the action, a welcome contrast. This action, used sometimes at the sides or below and inverted above, in one case helps to diminish the static aggregation of the assembling pentagram

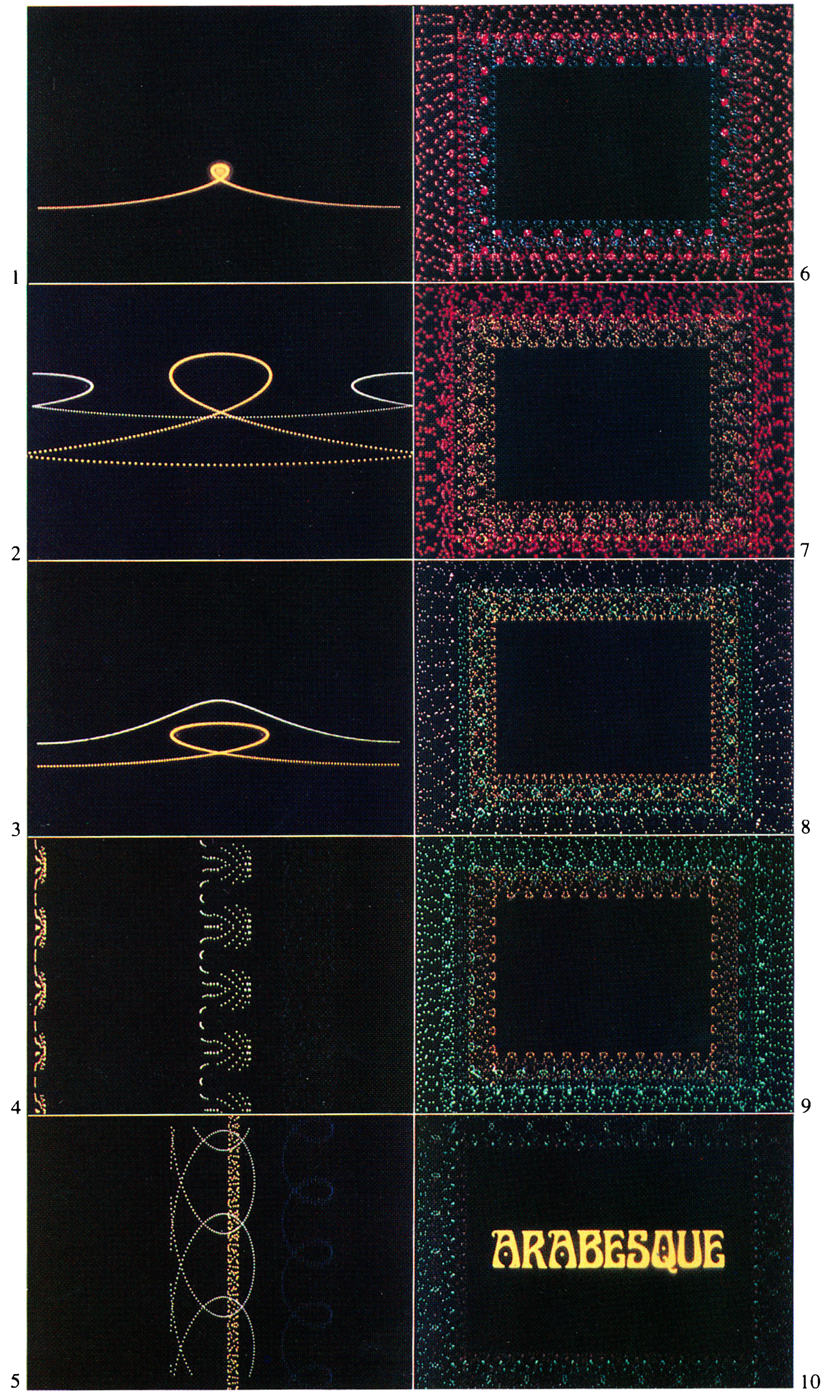


Figure 21

figures. It is an experimental device. I wonder if it will not one day be considered very naive. See Figures (16) and (19).

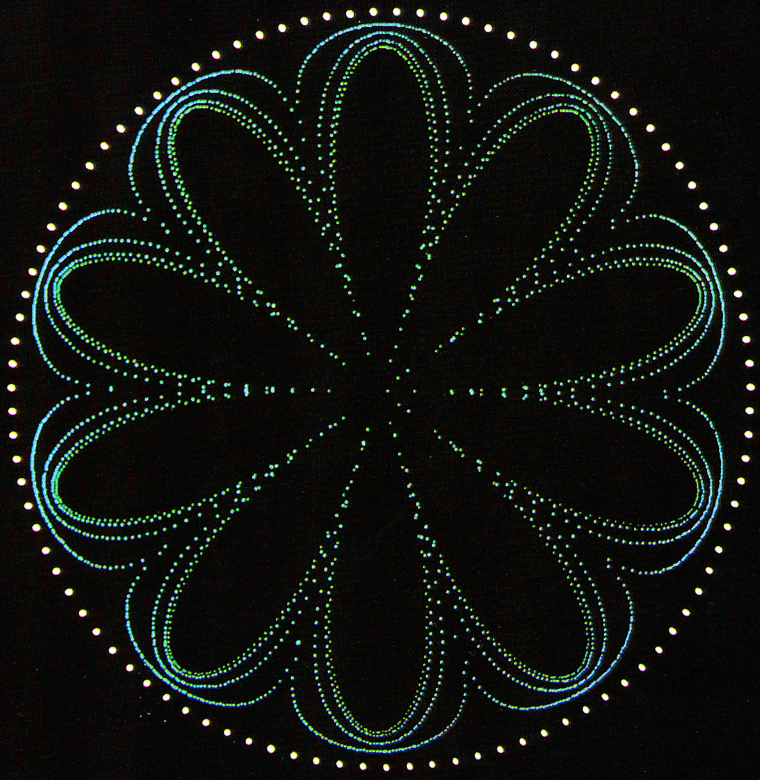
A second detail is a further elaboration of this framing device made into an ornate border used at the opening and ending titles. Not just a small piece of action around the 360th fraction, but longer segments from throughout the entire cycle are squeezed in the Y-axis, then repeated around the four sides of the frame. These in turn are repeated one upon another to produce the intricacies of the border pattern seen in the illustration, Figure (21).

Color throughout the film is the result of another exploration of photographic color dynamics. More dynamic than my other films, the color is in constant flux. Color changes almost every frame in smooth transformations by means of the installation of a color wheel at the optical focus of the condenser light source. The wheel is turned mechanically as a sequence of frames is filmed producing an ungainly-to-control but effective random serialization of the color patterning for the entire film.*

Music for *Arabesque* is related to its title and to my reasons for identifying with the subject. Islamic design, hand in hand with its geometry and calligraphy, was a source of inspiration in this work. I had recently come to know of Pythagorean influences which spread south and east from Greece into Islamic culture prior to its establishment in the monastic libraries of Europe. I sensed that the indirect meandering of the casual connections between Islamic ideas of cosmos, music, geometry and architecture had the quality and shape of an arabesque.

Once again, as with so many works before, I was obliged to search for given music to fit the completed essay of my visual composition. This time, I was reasonably satisfied with what was found. The improvisational sound track is the excellent work of an Iranian national scholar who teaches at UCLA, Manoocheher Sadeghi. The source of his performance was classical Iranian Santour music.

*See my references to the color problems, photographic vs. video phosphors, p. 90, Chapter VIII.



Chapter X

From Music to Visual Art and Back

Someday the term **digital harmony** may be a commonplace expression associated with a major evolution of twentieth century art technology. Because of digital harmony, music becomes visible. Performance escapes the bondage of time. Time achieves a totally new condition of substantiality. In this chapter I will explain each of these three ideas.

First, consider this nontechnical outline of a few principles that should be known about digital systems. Numerous microscopic memory locations hold signal *bits,* "on or off." In the nomenclature of digital electronics, a bit is the smallest subunit of signal. Usually bits cluster into *words* consisting of 8, 16, 36 or more bits:

(oxooxxxoxooxooox)

This row might be a 16 bit word with its first bit (at the right) "on" (x); its second, third and fourth bits "off" (o); its fifth bit, on and the next two, off, etc. reading right to left. The least significant bit is at the right.

This binary word translates into the number, 047221 (base 8). It could as well represent sixteen dots on a television screen or letters of a text or a fragment of an audio wave form. In ordinary memory devices, billions of bits may be stored more or less with security. They can be shifted around in digital systems, performing tasks of logic and manipulation and performing processes with images, sounds and words. This digital bit storage principle is probably among the century's greatest innovations.

Unlike film or the phonograph groove or even magnetic tape, the binary digital signal is almost invulnerable. This must be explained. In

fact, most digital signal carriers are quite as destructible as film, groove or tape. But optical or aural signals, translated into a pattern of digital bits, in effect, transform into a sum of on or off information.

Simply stated, on or off means just that. There is no halfway. Either the signal is there or it is not. There can be no progressive signal degeneration. This is ideally true when a signal is maintained and processed within a dependable computer system. Relocating, over and over, gigantic conglomerate patterns of bit signals can be accomplished almost without bit error.*

Regardless how the composer elects to compose the waveform and tempo of his composition, digital signal invulnerability permits him to play, section for section, over and over, at fast or slow speed, making corrections or changes as he chooses, as often and as extensively as he needs, but still retaining his composition on a record possessing that invulnerability.

Contrast this with the thirty-year-old magnetic recording technology. Generation for generation rerecording means progressive and intolerable degeneration of the quality of the signal.

All nondigital recording of sound or image requires start up and shut down time, needed in order for any system to reach play/record speed or to stop. These systems are all dependent upon some mechanical way of advancing the time record in actual physical motion past some sort of pickup reading or writing device. Temporal stability is a critical mechanical problem whether or not a particular system may include the best solid-state signal processing.

On the other hand, because all computer systems synchronize by precise clock timing (all solid-state, no moving parts), any music or optical sequence can be duplicated, edited, played and replayed, forward or backward, fast or slow, a fragment at a time. The signal is stored as a digital pattern that is called up at will at a specific clock rate from a memory device which routinely checks for signal (bit) error. The record

*For an example just how error free the binary signal can be in some digital devices: "In a high-performance magnetic disk memory the errors caused by dirt and other mechanical problems corrupt approximately one bit in 10 billion bits. Coding for the detection of errors reduces the error rate to one bit in 10 trillion bits." From *Scientific American*, August 1980, Volume 243, Number 2; R. M. White, Disk-Storage Technology p. 139.

is in fact free of background noise – an invulnerable image, including its time dimension, which is safe in memory until committed to one or another transportable storage package.

The typewriter on which I compose this text is a digital computer word processor. No matter how slowly I write, rewrite, erase and write again, all the text is stored in memory until I call for a printout. Then, my tedious daylong labor comes forth faultlessly onto paper at an exact character-per-second rate. If this were music or image – as it soon will be – the same editing and composing powers would prevail.

Now to discuss the three ideas of the opening paragraph which were:

1. Music becomes visible.
2. Performance escapes the bondage of time.
3. Time achieves a certain substantiality.

Music becomes visible through various developments. This book shows how a complementarity with a graphics of motion is one of music's present great potentials. In lesser ways altogether, digital music composing programs include applications of everyday computer graphic features. Waveform plots and envelope graphs directly aid composers. Time is better represented on a visual computer plot than by conventional musical notation. And there are other ways to employ graphic displays to aid in music composition.

Concerning the second idea – that a performer is somehow bound to the requirements of timing exactness, and will escape that bondage with future digital systems – the following is a brief view of the restraints which time places on our ability to perform music and how this may change.

My experience with early training in music is typical. At age nine or ten, I was given piano lessons. (Beethoven was, ... "standing in front of the clavier and weeping," probably at age four.*) The drudgery, more than tears, and the impatience with one's clumsy beginnings, and the insult to the ear, are obstacles that must be surmounted at an early age. I reached this conclusion in only a few months. Yet this was not exactly

*Alexander Wheelock Thayer, *Life of Beethoven*, revised and edited by Elliot Forbes (Princeton, 1967), p. 57.

the problem.

To fail or to succeed at a career in the performing arts comes by one's skill with **time.** One must meet the challenge to organize his senses and his muscular coordinations to the "microsecond." The timings are simply critical by the necessity to meet each musical moment on time. Actor, mime, pianist, orator, comic or violinist, all show this mastery with time. Training to maintain that skill demands their attention and practice throughout the remainder of a career.

A real microsecond (not my figurative use of the term, as above) can be divided in half, then quartered, then halved and otherwise divided several ways by casual choice of a computer's programming parameters. The point is, timing precision is easy. Performance constraints with time are surmounted, not by training, but by the capability to shape and secure a final perfect record by the computer's editing process as noted in my introductory paragraphs of this chapter. Thus performance escapes the bondage of time; but I would imagine this is an insufficient argument and so will offer another.

If weak in composition, this century has produced an extraordinary proliferation of sublime solo and ensemble performance. Probably more and greater world renowned soloists and orchestras perform today than in any previous epoch. Few would accept any argument on behalf of synthesized Bach, whether by synthesizer or by computer, so I must continue on with the argument for a digital system's role in future performance functions.

Bach manipulated the *Musical Offering* theme assuming, and probably accepting without question or complaint, the known constraints of performance and instrument. Today altered scopes of performance and instruments might suggest to him some different manipulations. The *Offering* has often been transcribed for some such reasons. Bach's visions might change once more with an instrument to interweave composition with performance. He might welcome a means to combine writing, listening and rewriting with ease – correcting or deleting and refining closer to his mind and feelings than possible with pen on paper. For all that, the image of Bach at a computer terminal is as sentimental and ludicrous as the cliche it has become in popular home computer journals.

If timing can be matched micromoment for moment by computer, what about the "feeling" of a performance? The subtlety of musical experience is another matter: who should judge matters as to how each detail of a work should "feel," if not the composer himself? Bach at a computer keyboard is less dubious than programmers "having a go" at interpreting Bach. It is wrong, of course, and anachronistic, to attempt to recreate Baroque music with a computer.

However, it is not wrong at all to compose original work for this new instrumentation. This, then, is the most powerful argument. The argument is as true today as it was when Bach himself composed the book of studies that explored *The Well-Tempered Clavier, i.e:* the compromised, adjusted and retuned keyboard, a technical development just becoming accepted in his time. It would be difficult to overstate the advantages which reside in a technical advancement so far-reaching as this revolution in the very process of music making. It is irrelevant that "player pianos" and other nineteenth century automata, the music box, calliope and all the others, were doomed to be evaluated merely as novelties. This revolution relates to a humane compromise with the very essentials of the ways of making music. Digital systems procedures greatly improve the method for making music by several magnitudes of importance. This will be explained as a third point of argument.

Incidentally there is a note of hope for those who know music well and rightfully loathe nearly every piece of "electronic" music which they have heard. At this writing, I believe we approach a benchmark in comprehending new theories of tone generation by digital waveform synthesis. I am not sufficiently informed to include details here except to repeat my own observation that most electronic instruments up to the beginning of this decade have been made upon false principles, proven false by the ear. Thus, despite this hatchet upon the past, my optimism for the future of digital systems is informed by new theoretical work upon waveform synthesis. My expectation for genuine musical enjoyment is unswerving.

The third point of this chapter, about the substantiality of time, is related to all the above arguments – as it were, the complement to them. Music is fleeting. This very old observation, repeated by scientists, anthropologists and critics, makes sense, although the performer hardly

knows of this. As he practices for performance he loses the sense of the fleeting nature of music because he plays and plays again each detail, shaping it like clay. Its substantiality is in his hands; he feels something more solid than gossamer in the fleeting pattern of tone.

Music, as a digital record in a computer composing instrument, is accessible to the composer in the **performer's** sense of its substantiality. With digital system repeatability, time gains that substantiality. The repeatability and the accessibility we gain, if a musical signal is generated as digital signal in a computer, systematically improves its "materiality." We gain the power to shape the musical signal as substance.

The composer rarely had this power. Performance thus escapes its previously permanent status as the historic hostage to the "trained" performer or orchestral group who, ostensibly, are the masters with time. The fleeting insubstantiality of music is transformed. Composing becomes more like molding clay, because of the hands-on process of digital memory manipulations. The composer may mold this particular substance with his instant, interactive responses to the sensitivity of his own ear. Time is mastered and turned into **substance.**

Add to this substantiated hands-on process of sound, the same hands-on process of the color image in motion. A revolution in intuitional intimacy with sound and color is the result. The distances from music to visual art and back have been shortened by this newfound substantiality. The digital hardware is at hand. The software calls for a collective exploration of principles of digital harmony as they apply to image and sound alike.

Chapter XI

Summary and Prospect

Less than thirty years have passed since the beginning of computer graphics. We are witnessing the materialization of another fertile domain of architectonic pattern. Before us lies an optical domain which may prove to be quite as vast as the historic world of music. I work within this visual domain of harmonic potentialities experiencing the strong challenge to creative skill that composers of the baroque or classic epochs must have felt.

Now and then throughout the several centuries of musical life in Europe, through the music of some scholarly composers one feels their sense of wonder at the splendor of musical possibilities spread before them. One is reminded of Padre Antonio Soler or Domenico Scarlatti, in eighteenth century Spain; both consummated their lives engrossed in constructing works that explore merely within a few particular forms for the keyboard – essays numbering many many hundreds. These were exercises in the minutiae of harmonic complexity. They possess an elegance of logic and style which is prized today, not the least, among our mathematicians. Tidy as their riddles were – their answers are fresh today with unexpected novelty and pleasure.

Few other preoccupations brought such consistent rewards. Nations were founded during that era, and history books record vast military enterprises side by side with mechanical, scientific and philosophical refinement and invention. History instills an air of distant quaintness in our minds, but we revere, celebrate and enjoy intimately the music of that age today as if it were our own living present. As indeed it is. What else of their private thought do we know so well as we know their

literature and that extraordinary music?

Is it possible we could witness a repetition of one of those historic chapters? Could we participate in another age of invention devoted to the curiosity of the intellect and artistic aspiration? Is it possible to entertain the idea of repeating such an epoch, mindful today of some of the grim alternatives? Might our culture, after its hundreds of years of hard enterprise and its material triumphs and failures, entertain the mere idea of less of that and more of this – this kind of intellectual software and invention?

Technically foreseeable and without waste or further harm to environment, it could happen. Indeed, I see an epoch which in many ways might rival the intellectual curiosity and creativity of the great generations of European music. I know that the marvels of video and computer technology would allow this. I know there is a widespread disposition toward the idea and there are the skills for an unprecedented creativity at our universities and among the young generations. Hand in hand with these new dispositions, it is rumored that we stand at the threshold of an altogether different production and consumption structuring in the marketplace for arts, high and low.

Epilogue

There remain, no doubt, objections to the picture presented by this book. Some would call my ideas just more unneeded science fiction. And again some objection might be due to a misreading of my own beliefs regarding cybernetic aspects of the computer.

If this is necessary, then, forthwith I will say that I am on the side of Joseph Weizenbaum, not my friend Marvin Minsky, as to whether or not computers will "... write really good music or draw highly meaningful pictures...."* Flatly I will express aloud my disbelief at the implication of these words. Computers will do no such thing, of themselves – not ever! Indeed art is a matter of, "judgment – not calculation."

There are less subtle misunderstandings. There are attitudes that assume the legitimacy of a Stradivarius or a Steinway as necessary musi-

*Joseph Weizenbaum, *Computer Power and Human Reason: From Judgment to Calculation* (San Francisco, 1976), p. 157.

cal "machines." (No one expects a piano to "write really good music," fortunately.) But many of those persons, who accept the role of musical instruments, can see no possibility that a computer may function anywhere in the highly specialized environments of the fine arts or the popular arts.

The high-water mark of mechanical invention reached in this century was not high enough. Consensus holds that the two-century-old Stradivarius is supreme in its field today. Man-machine responses are nowhere else as sensitive as those between a man and a violin. The best technology of this century has not forestalled the decline of our once bold faith in machines. And even the general idea of technological art is much discredited, though probably for good reasons which spilled from demonstrations in unlikely places intended to "prove" technological art.

Joseph Weizenbaum's concern, and the debate, is obviously over more comprehensive issues. Of course, I'm not qualified to add to a debate on the serious issue of computer power *vs.* human reason. I have wanted only to dispel misapprehensions that could jeopardize the thesis of this book on the future of an art which is intimately bound to computer technology's instrumentation.

On the issue of geometry *vs.* biomorphic form, usually meaning the hand-drawn image, objections frequently come from those on the other side of a controversy that can be traced throughout cultural history. From classic *vs.* romantic and Apollonian *vs.* Dionysian divisions, from Mondrian or Mies van der Rohe *vs.* Kandinsky or Gaudi, obviously the earth has accommodated both sides, for a long time – if not peacefully. Overrating divisions of this sort is a pastime.

Plato contributed these words on behalf of geometric form, apparently an issue in his era:

> For I say that these things are beautiful not in relation to something else, but naturally and permanently beautiful, in and of themselves, and give certain characteristic pleasures,... And colors of this sort are beautiful because they have the same character and produce the same pleasures.*

Sometimes the dichotomy between geometric and biomorphic form manifests as logic *vs.* sentiment, or abstraction *vs.* representation. For some, there is a pervasive distaste for the geometrical image or abstrac-

**Philebus*, 51c. Quoted in Rickey, *Constructivism*, p. 9.

tion. The complement of this feeling motivates the effort to anthropomorphize geometry, abstraction and machines. So Disney required that even the "abstraction" of a Bach fugue be turned into representations of parts of the violin, Beethoven into centaurs and nymphs and Stravinsky into prehistoric monsters in local tar-pits. In truth, these are all obvious misrepresentations and too clever – like naming a computer "Hal."*

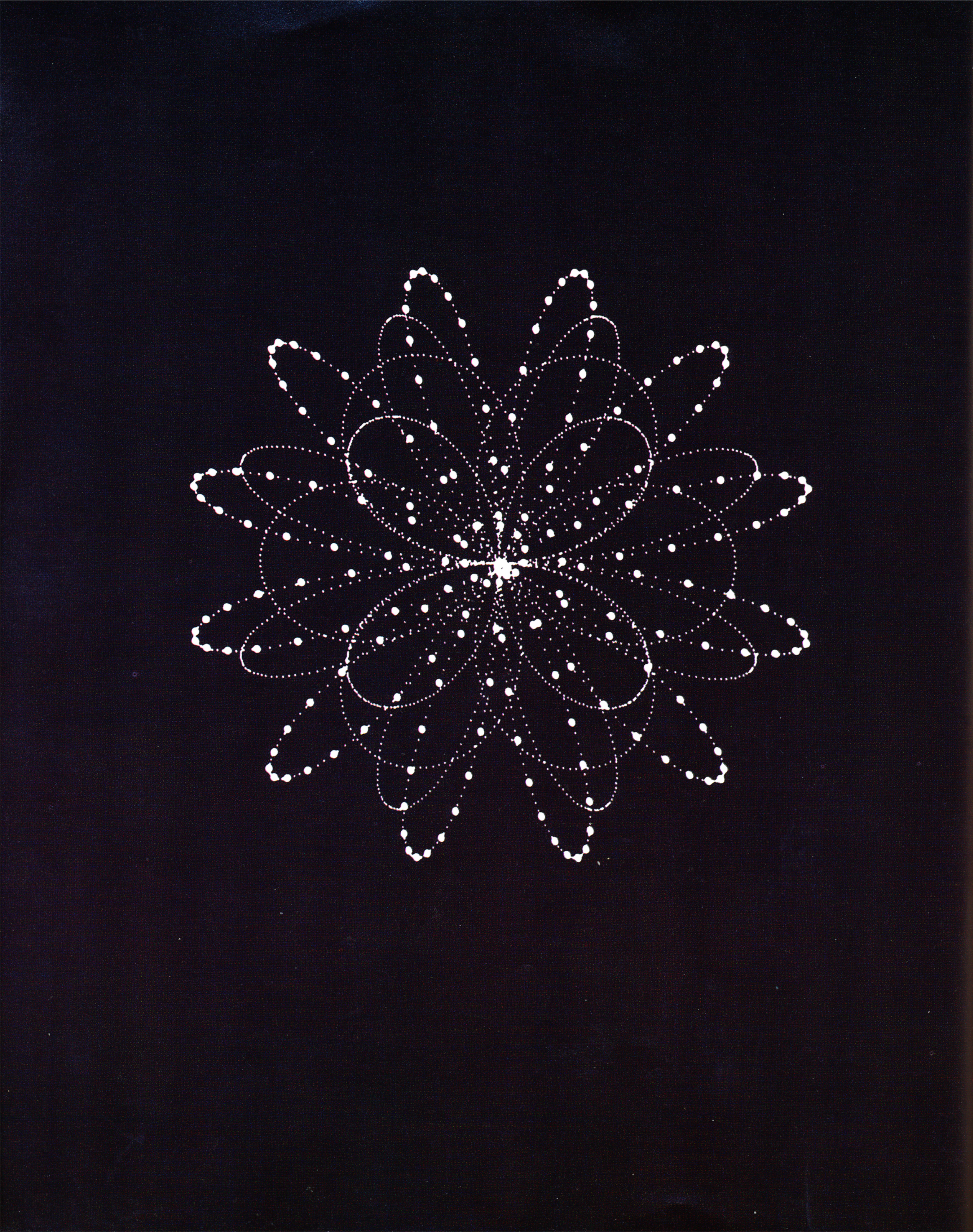
Geometry and reality are not disparate entities, one cold and impersonal, nor is the other all that lovable, of course. The entire universe, and the earth's biosphere of plant and animal, and the idiosyncrasies of geography, are in fact, only the "idiosyncrasies" of geometry. All derive from one geometry, as I see it; all derive from one mind, for all I know.

Because my computer compositions thus far manipulated points, straight lines or simple constructions of these elements, this does not spell the computer's complete visual repertoire. Computer geometry, infinitely diverse, as in nature itself, constrains graphic diversity merely as a limit of resolution. The higher the resolution, the greater the visual diversity.° This axiom is true in X Y Z dimensions of visual space, sound and the dimension of time as well.

Boundaries of resolution expand year after year as computer memory expands. Computer technology's peculiar ominous novelty diminishes year by year. As surely as the piano's refinement consistently progressed over a few hundred years, another process of refinement is occurring today. The instrumentalities of **digital harmony** for music and art become progressively more available to the artist and he will use these for greatness as the artist has consistently used the instruments and the ideas of each era to recall **its** greatness.

Long live this revolution.

*See *Fantasia* and *2001: A Space Odyssey.*
°See p. 80, Figure 12. Also consider some of the elaborate detail of *Arabesque*.



Chapter XII

Do It Yourself

This chapter contains the implementation of the same Pascal programs that were used to generate the **digital harmony** patterns that illustrate text in Figures (1) and (13) to be found on pp. 50 and 98. Of course you should refer to the text of Chapters V and VI to understand the function of differential dynamics and be aware that patterns generated by these rudimentary programs are not interesting as one picture in itself but are basically patterns of motion. In my system, I use the *UCSD* Pascal version 1.5, and in the past, I have used Basic and Fortran. In order to create digital harmony on your own, you will need a system which runs Pascal (or, if not, it will be necessary to convert the image generating algorithms into whatever language you do have); in addition, you should have a reasonably high-quality CRT display system.*

Still 100 x 100 addressable pixels will suffice if you don't mind all your designs looking slightly old-fashioned like quaint needlepoint. This is in fact no laughing matter; to the contrary, a scale of resolution as low as 100, should (and will) render graphics of elegance superior to any I have yet seen. Again I stress that our interest is no longer with "pretty pictures;" we want to create motion that may be pretty, elegant or funny but not dumb. Action, the subject of this book from end to end, points the way beyond the obvious shortcomings of twinkle boxes and most patterning programs. As stated elsewhere, many displays filled with "boiling" action seem quite static nevertheless, due to the pointlessness

*A handbook containing details of these programs in Fortran and Basic, and more general instructions, will be available soon.

of the action or its unimaginative planning or its triviality.

For capturing the action-patterns of these programs, a video recorder would serve except for a limitation which must be explained this way: few small systems are fast enough to generate graphics in motion in real time. The thousands of stepping images of a motion sequence are generated slowly in small computers; even one image per minute is a reasonable computing speed. At present, home video recording machines do not take images one frame at a time (as they will soon). So, a movie camera is needed, with a means of controlling the shutter and film advance of the camera from your software.

This latter step generally involves a subroutine which can control a couple of bits on an input/output port, and may have to be written in assembly language code depending upon the specific high-level language you are using (see detailed discussions of interfacing cine cameras to computers in various issues of *Tekniques*, the Tektronix monthly journal for graphics users of the 4051).

The simplest differential pattern that we can generate is at column A of Figure (1) p. 50; see the listing on p. 134. The key variables which you should set in the Pascal program are NPOINTS, which is the number of points within one frame; NFRAMES, the number of frames which the program will make; STEPSTART, controls the starting pattern beginning the action at frame 1; STEPEND, determines the ending pattern at frame (NFRAMES). For your initial test, select the following values NPOINTS:=60, STEPSTART:=0.0, STEPEND:=1.0 and NFRAMES:=240 for an action sequence to run ten seconds on a film running at the common 24 frames per second rate. Or you could set NFRAMES:=9 and all the parameters at the values printed in the listing, to duplicate exactly the nine frames of the illustration, column A Figure (1) and compare the results.

These listings contain explanatory {comments} so marked. General remarks about all of the programs will follow these references to each of the three different variations.

Now, if you look at the listing, p. 135, for Column B & C, notice that the action is within a circular field and is expressed by polar coordinates; to generate this type of pattern, a new variable is needed: RADIUS. Selecting a radius exposes the points to a differential dynamic force

which increases with the point's position along the radius. Each point moves at its own angular rate differentially according to its position along the radius. For these examples, the degree of differential introduced is predetermined in the program by variable A, and you can manipulate the equation which gives value to A once you have more experience with the technique.

Setting STEPEND:=1.0 and NFRAME:=240 as above will complete one full cycle which returns all the points to their starting position along the original radius line. Again, if you film this sequence, the running time will be ten seconds, a rate which will prove to be too fast to see all of the whole fraction patterns as they occur. Add a zero to the parameter. NFRAMES:=2400 simply lengthens the period of action by a factor of ten; you will see how much detail of action is revealed. Increase NPOINTS:=360 (the value used in *Arabesque*) to see how much more detailed the pattern of each frame becomes.

At this point, a footnote of interest: compare types of drawn animation with this new medium of computer graphics. Were you to draw by hand the points of this sequence (which you simply could not do, incidentally) you might have the following thoughts about the unmanageability of the task. Bad enough to make 240 drawings, but what about 2400 drawings? Unthinkable. Note that having changed your program from NFRAMES:=240, to NFRAMES:=2400, you merely added one zero to make 2160 more images. That's easier than making 2160 drawings, but the point is not to make art easier, of course. The first idea is the important one to consider; you simply cannot draw this kind of pattern in motion by any way other than by digital computer graphics. This is an unprecedented new fact and a new opportunity in the visual arts.

In the Column B & C program, not only is the action within a circular region as pictured, but the line also wraps around the center. All of the rose curves of the type $R = a \sin n (\Theta)$ may be generated by some slight modifications of this program. The numerous polar coordinate type patterns which appear dynamically as "moments" of harmonic resonance (more orderly in appearance than the immediately preceding and succeeding patterns) can be generated. For example, see Figure (5) in which a 4-lobed rose transforms into a 3-lobed rose by a progression of intermediate, less simple patterns. Refer to the chapter VI

discussion of that illustration. TD and RD type parameters can be written into the above polar coordinate equation controlling theta and radius.

Figure (13) of Chapter IX on page 98, illustrates the root action principle which is used with variations throughout the entire composition of my film *Arabesque*. The listing, p. 136 generates a circle of points which move as outlined in the text. Setting NPOINTS:=60, as listed, allows the program to compute reasonably faster than it would if the positions of 360 points must be calculated. Obviously, wise choices of your options in selecting values for NPOINTS: and NFRAMES: allows you to explore these fields of pattern and action most productively.

Again, as with the other examples, setting STEPEND:=1.0 produces one complete cycle. Selecting with ingenuity and imagination all the other values of any algorithm allows you to explore the variety of dynamic pattern waiting to be mined – like gold – in any differential pattern system such as this.

Reading Chapter IX, the analysis of *Arabesque,* will serve to suggest further variations upon this simple program which I explored only for a period of four or five months. Certainly this program concept was not deeply "mined" for its fullest possibilities. Perhaps one third of all the film material that was prepared for the film was rejected and might one day be used in another film. It is significant to realize how meager my experience was in exploring the *Arabesque* material, and how limited all exploration is to date, in this area of computer graphics.*

Here is a vein of "ore" differing from the usual. Mining this vein may be an infinite process. This "vein" opens to our exploration an infinity such as the twelve tones of music have to offer. I'll try another metaphor: we haven't explored here as long, or as well, as we have explored the moon.

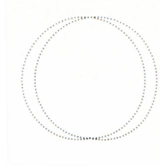
For example, you can add to any of the three simple programs listed on these pages, many forms of mirror image "reflections." If you do so you will soon see how to recreate an image sequence like the flip-book.

*The full-page chapter heads are an example of another kind of exploration. The multi-lobed patterns of the polar-coordinate family presented in Figures (3), (4) and (5) are treated to a few of the variations that derive from parametric variables and multiple exposures with various color filters. Each Chapter number is associated with the number of lobes of that pattern.

By running through a reiteration loop of some sort, with X or Y or both coordinates inverted, or switching "TD" and "RD" parameters similarly, the combination of original and its reiteration form symmetries about a vertical or horizontal axis. Symmetries, doublings, rotations, counterpoints or canons (following one sequence with another and another in staggered order), these are only the most obvious procedures among an enormous range of possibilities for pattern, motion pattern enrichment and variety.

It's up to you, do it yourself. Do it!

```
  PROGRAM COLUMNA;
{ FIGURE (1) COLUMN A   - DIFFERENTIAL POINTS ON A STRAIGHT LINE MODULUS }
{ COPYRIGHT 5/25/80 BY JOHN WHITNEY            - PREPARED BY PAUL ROTHER }
{ ADAPTED FOR APPLE - II }

CONST   DEG=0.0174533;                        { CONVERTS DEGREE TO RADIAN }

VAR     TIME,STEP,
        STEPSTART,STEPEND,
        X,Y,
        LENGTH,XLEFT,YBOTTOM  :REAL;

        POINT,NPOINTS,
        FRAME,NFRAMES         :INTEGER;

(*$IAPPLEDRV.TEXT*)                     { INCLUDE APPLE GRAPHICS DRIVER }

BEGIN

   NPOINTS        :=60;                 { NUMBER OF POINTS IN A DISPLAY }
   NFRAMES        := 9;                 { NUMBER OF FRAMES FOR THIS RUN }
   STEPSTART      := 0;                 { STEP AT THE FIRST FRAME       }
   STEPEND        :=1/60;               { STEP AT THE LAST FRAME        }

   LENGTH         :=170;                { LENGTH }
   XLEFT          := 38;                { X LEFT }
   YBOTTOM        := 18;                { Y BOTTOM }

   FOR FRAME:=1 TO NFRAMES DO BEGIN

         ERASE;

         TIME:=( FRAME-1 ) / ( NFRAMES-1 );
         STEP:= STEPSTART + ( TIME * ( STEPEND - STEPSTART ));
                             { STEP IN OVERALL CYCLE ( 1=FULL CYCLE ) }

         FOR POINT:=1 TO NPOINTS DO BEGIN
               X:= XLEFT + LENGTH * POINT/NPOINTS ;
               Y:= LENGTH * POINT * STEP ;
               Y:= YBOTTOM + ( ROUND(Y) MOD ROUND(LENGTH) );
                                           { MODULO FUNCTION WITHIN FIELD }
               DRAWXY( ROUND(X) , ROUND(Y) );
            END;

         CAMERA(120);                                { EXPOSE ONE FRAME }

      END;
      READLN;                                   { WAIT FOR USER RESPONSE }
      TEXTMODE;                       { RETURN APPLE SYSTEM TO TEXTMODE }
END.
```



```
  PROGRAM COLUMNBC ;
{ FIGURE (1) COLUMNS B & C - DIFFERENTIAL POINTS ON A POLAR COORDINATE FIELD }
{ COPYRIGHT 5/25/80 BY JOHN WHITNEY                  - PREPARED BY PAUL ROTHER }
{ ADAPTED FOR APPLE - II }

CONST   DEG=0.0174533;                          { CONVERTS DEGREE TO RADIAN }

VAR     TIME,STEP,
        STEPSTART,STEPEND,
        A,X,Y,
        RADIUS,XCENTER,YCENTER  :REAL;

        POINT,NPOINTS,
        FRAME,NFRAMES           :INTEGER;

(*$IAPPLEDRV.TEXT*)                         { INCLUDE APPLE GRAPHICS DRIVER }

BEGIN

   NPOINTS      :=60;                       { NUMBER OF POINTS IN A DISPLAY }
   NFRAMES      := 9;                       { NUMBER OF FRAMES FOR THIS RUN }
   STEPSTART    := 0;                       { STEP AT THE FIRST FRAME       }
   STEPEND      :=1/60;                     { STEP AT THE LAST FRAME        }

   RADIUS       := 85;                      { RADIUS   }
   XCENTER      :=140;                      { X CENTER }
   YCENTER      := 96;                      { Y CENTER }

   FOR FRAME:=1 TO NFRAMES DO
      BEGIN
         ERASE;

         TIME:=( FRAME-1 ) / ( NFRAMES-1 );

         STEP:= STEPSTART + ( TIME * ( STEPEND - STEPSTART ));
                                 { STEP IN OVERALL CYCLE ( 1=FULL CYCLE ) }
         FOR POINT:=1 TO NPOINTS DO
            BEGIN
               A:= 360 * STEP * POINT;                 { + = CCW ROTATION }

               X:=XCENTER + COS(A*DEG) * (POINT/NPOINTS) * RADIUS ;
               Y:=YCENTER + SIN(A*DEG) * (POINT/NPOINTS) * RADIUS ;

               DRAWXY( ROUND(X), ROUND(Y));
            END;

         CAMERA(120);                                  { EXPOSE ONE FRAME }

      END;
      READLN;                                   { WAIT FOR USER RESPONSE }
      TEXTMODE;                        { RETURN APPLE SYSTEM TO TEXTMODE }
   END.
```

```
  PROGRAM ARABESQUE ;
{ FIGURE (13)           - DIFFERENTIAL POINTS AROUND A CIRCLE X-STEP MODULUS }
{ COPYRIGHT 5/25/80 BY JOHN WHITNEY                    - PREPARED BY PAUL ROTHER }
{ ADAPTED FOR APPLE - II }

CONST   DEG=0.0174533;                           { CONVERTS DEGREE TO RADIAN }

VAR     TIME,STEP,
        STEPSTART,STEPEND,
        A,X,Y,R,
        RADIUS,XCENTER,YCENTER :REAL;

        POINT,NPOINTS,
        FRAME,NFRAMES           :INTEGER;

(*$IAPPLEDRV.TEXT*)                          { INCLUDE APPLE GRAPHICS DRIVER }

BEGIN

   NPOINTS      :=60;                        { NUMBER OF POINTS IN A DISPLAY }
   NFRAMES      := 9;                        { NUMBER OF FRAMES FOR THIS RUN }
   STEPSTART    := 0;                        { STEP AT THE FIRST FRAME       }
   STEPEND      :=1/60;                      { STEP AT THE LAST FRAME        }

   RADIUS       := 60;                       { RADIUS   }
   XCENTER      :=140;                       { X CENTER }
   YCENTER      := 96;                       { Y CENTER }


   FOR FRAME:=1 TO NFRAMES DO
      BEGIN
         ERASE;

         TIME:=( FRAME-1 )/( NFRAMES-1 );

         STEP:= STEPSTART + ( TIME * ( STEPEND - STEPSTART ));

                                  { STEP IN OVERALL CYCLE ( 1=FULL CYCLE ) }

         FOR POINT:=1 TO NPOINTS DO
            BEGIN
               A:= -90 + 360 * POINT / NPOINTS ;

               R:= 3 * RADIUS ;
               X:= COS(A*DEG) * RADIUS + POINT * STEP * R ;
               X:= XCENTER - (R/2) + ( ROUND(X+(R/2)) MOD ROUND(R) );

               Y:= YCENTER + SIN(A*DEG) * RADIUS ;

               DRAWXY( ROUND(X) , ROUND(Y) );
            END;

      CAMERA(120);                                       { EXPOSE ONE FRAME }

   END;
   READLN;                                          { WAIT FOR USER RESPONSE }
   TEXTMODE;                                { RETURN APPLE SYSTEM TO TEXTMODE }
END.
```

```
{ FILE APPLEDRV.TEXT        - APPLE GRAPHICS DRIVER WITH TURTLE GRAPHICS }
{ COPYRIGHT 5/25/80 BY JOHN WHITNEY            - PREPARED BY PAUL ROTHER }
{ ADAPTED FOR APPLE - II }

{ THIS VERSION WAS SUGGESTED BY CARL HELMERS.  IT IS ADAPTED TO WORK     }
{ ON AN APPLE WITH TURTLE GRAPHICS AND A TELEVISION DISPLAY.  OTHER      }
{ HARDWARE WOULD REQUIRE OTHER MODIFICATIONS.  -  JW                     }

USES TURTLEGRAPHICS, TRANSCEND;

PROCEDURE CAMERA(TIME:INTEGER); { SHOOT ONE FRAME                        }
                                { CAMERA CONNECTED TO AN#0 GAME I/O PORT }
                                { I/O IS MEMORY MAPPED AT C058H & C059H  }

VAR   J       :INTEGER;
      ANYCHAR :CHAR;
      CAM     :RECORD CASE BOOLEAN OF
                 TRUE  :(A: INTEGER);
                 FALSE :(C: ^CHAR  )
               END;
BEGIN
   CAM.A:=-16295;               { C059H ADDRESS - SET AN#0 OUTPUT ="1"   }
   ANYCHAR:=CAM.C^;             { OPEN SHUTTER (SET TIME FOR ANY CAMERA) }
                                { EXPERIMENT WILL DETERMINE THE OPTIMUM  }
                                { SETTING HERE FOR YOUR CAMERA AND FILM  }

   FOR J:=1 TO 400 DO J:=J;     { WAIT FOR CAMERA  (SET FOR YOUR CAMERA) }

   CAM.A:=-16296;               { C058H ADDRESS - RESET AN#0 OUTPUT ="0" }
   ANYCHAR:=CAM.C^;             { CLOSE SHUTTER    (SET FOR YOUR CAMERA) }


   FOR J:=1 TO TIME DO J:=J;                     { WAIT FOR CAMERA AGAIN }
END;

PROCEDURE DRAWXY(X,Y:INTEGER);        { DRAW POINT AT X,Y ON APPLE SCREEN }
BEGIN
   PENCOLOR(NONE);
   MOVETO(X,Y);
   PENCOLOR(WHITE);
   MOVETO(X,Y);
END;

PROCEDURE ERASE;                      { ERASE SCREEN, RETURN TO GRAFMODE }
BEGIN
   INITTURTLE;
END;
```

Audio-Visual Music: Color Music– Abstract Film 1944

This article from 1944 (presented here in a very slightly abridged version) offers a breathtakingly farsighted comprehension of new technology and its impact on the arts. The young Whitney brothers, having completed their truly revolutionary, modernist *Five Abstract Film Exercises*, prove here that they understood, deeply, the philosophical and sociological ("Marshall McLuhan") implications of the film medium as well as the infant television industry – implications that only now, 40 years later, are finally coming to fruition.

It is perhaps hard for us today, with a generation of hindsight schooled by many recent radical experiments in the auditory and visual arts, to realize how revolutionary the *Five Film Exercises* seemed at that time, but many people who witnessed the first screenings of those films (including sculptor Harry Bertoia and Jacques Ledoux of the Brussels festival) have told me how shocked audiences were by the "unearthly," "electronic" music and the luminous "neon" images that seemed to have dropped into our time zone somehow from the science-fiction future.

Another index of the absolute pioneer status of these young artists is their paragraph about the unfeasibility of full-screen sequences of color without graphic forms. I am reminded of the touching passage in Kandinsky's *Reminiscences* wherein he describes his fear and trembling upon "discovering" his first nonobjective painting – one of his own representational canvases accidentally turned on its side in the twilit studio – which he didn't quite know what to make of. Coincidentally, about that same time (1944) Oskar Fischinger experimented with full-screen color in *Color Rhythm* and *Radio Dynamics* – films he never showed publicly – and Dwinell Grant in New York prepared a *Color Sequence* which he found too disquieting and shelved for 30 years. But 10 years later, in the mid-50s, James Whitney would use full-screen color brilliantly in his *Yantra*, and more than 20 years later Tony Conrad and Paul Sharits would exploit color flickers in films hailed as breakthroughs by the Structural Film movement. In another dozen years from now, after videodiscs have published the entire body of audio-visual music (greatly enlarged by that time), then, perhaps, we will be able to see *Five Film Exercises* in their true perspective – as the first full-blown works of a Renaissance in the arts. – *W. M.*

As technological control of new art resources has matured, so has a new generation of young people whose environment itself has been a conditioning factor toward acceptance of these resources as material of aesthetic experience. The main outlets of creative experience with many individuals of this generation is somehow channeled in modern technology. When this generation seeks a means of self-expression, they quite

naturally take up photography, engage in amateur radio activity or build a new automobile of private design from old parts. Little can be said here of the exact processes involved, but in general, it is now clear that this "amateurism" as a conditioning factor spreads, as much as anything else, receptivity to new media of creative expression. This promises future **technology-based** arts of great popularity.

Since the development of techniques of animated moving pictures, an art consisting of movement of visual elements within a temporal pattern has been a possibility. Such an art would possess all the rich appeal of music itself. With the development of sound cinematography, audio-visual relationships in complete harmony and unity of feeling became possible, foretelling an art utterly unique in this age. The small but vigorous abstract art movement of today may appear historically as the precursor to this abstract cinema.

That the sound-drama film occupies the entire present motion picture industry may be only a temporary condition. Certainly there is promise of change here with the development of television. With the shuffle that is bound to accompany the spread of television, emphasis upon the currently dominant category of filmed drama may subside so as to present in clearer perspective the full field of the cinema art, in which the commercial drama-film would be seen as only one fragment of a graduated scale of cinematic art. Such a scale would also include, in various proportions, the documentary, the surrealist/poetic and the so-called "abstract" film.

The following remarks are based upon experience acquired during the past five-years' work with animated abstract films. These remarks attempt to clarify certain issues centering around this new art medium based on technological resources that either are in use or are possible today.

Perhaps no other art received so much attention and was the subject of such experimentation so prematurely. Leonardo speculated on the similarity of color and tone in *De Sensu.* Starting in the seventeenth century, a line of experimenters with color-organs stretches to the latter part of the nineteenth century when at last the invention of the incandescent lamp and progress in optics made the color organ slightly more practical.

Today, the existence of a variety of technical means, the imminent

promise of television as an agent of communication to a broad audience, and the past thirty years of experiment by two diverse schools – the abstract film group and the experimenters with "color music" – has brought the medium to the threshold of actuality. Discussion and definition of its issues and structural problems, therefore, no longer remains just purely speculative, without practical experience.

The term *abstract film,* is unfortunate, but still more unfortunately, as yet no term has been coined to name an art having such unique qualities that it fits poorly into either music or graphic art categories. *Film,* though currently appropriate for the phrase, will become more and more misleading with the increased application of television technology. But the word *abstract* has more misleading connotations today than ever before, since it is widely used in current painting vocabulary.

This medium is no more or less abstract than music, so it should not be burdened with the issue of abstraction in its very name. That it exists obviously on a level of abstraction should be a natural assumption, as it is with music.

While "abstract painting" posits a silent visual art of stasis, the technological potential of sound film and television dictates greater concern here with the future of a medium uniting kinetic sight and sound. We will speak of the medium as **audio-visual-music** for want of a better name.

Since animation procedures are the means of achieving motion, the subject of tempo in audio-visual-music will deal with various units consisting of various quantities of frames. The illusion of movement is achieved by a series of static images projected in rapid sequence, of course. This new audio-visual-music image, whether animated frame by frame or created by other means for screen or television, must adapt its basic temporal structure to the frequency of the frame projection rate. As a general principle, both sound and image should have a common time unit which would be the frequency of projected frames. Music notation, where it is used, would thus be converted from metronomic time values to frame-unit values.

The fact that movement is not continuous actually limits rhythmic possibilities in the visual domain relative to that of the sound. For example, the minimum time unit must be one frame (1/24th second), while

the only possible next longer unit must be twice that amount or two frames of image. On the other hand, while music notes of shorter duration than 1/24th second occur infrequently, notes of intermediate duration or periodicity (between 1/24th and twice and three times that 1/24th fraction) are common. And so the animated image cannot be easily synchronized to these intermediate frequencies. Thus, it may be reasoned that film possesses an inherent rhythm of its own which often is immutable.

Another determinant of audio-visual-music is the persistence-of-vision, and certain natural differences in our response to rhythm by eye and ear. With regard to our response to rapid rhythmic motions and alterations, some are even painful to the eye.

A third determinant and difference between image-time and sound-time is the relation of graphic space to time. Space/time considerations are forced into a special kind of preeminence. No movement exists that is oblivious to time. No shape – no space – eludes movement considerations that are free of time considerations. Space and time here are inseparable in a very real sense. A tiny animated shape creating a rhythmic movement in a given space may produce one effect. The same action magnified many times, so as to fill the entire screen area, produces a radically different temporal experience even though the **time** of each may be exactly the same. The difference is qualitative to a degree that variation upon a thematic idea is not clear by simple magnification or reduction of size.

Experiment has indicated how ineffective full-screen passages of color, without other graphic form, can be – how ineffectual these are as a device to carry any rhythmic idea. Unless they are supported by a strong musical reinforcement, the effect is surprisingly ambiguous. Such sequences of various fields of color, which might be introduced as a thematic idea later to be subjected to variation and development, would seem to be foredoomed. And this observation reflects the apparent failure of all color-music experiments that treated color as an independent visual entity having no relation to form or shape.

What then can be the role of color in audio-visual-music? It is still the most vital element of the total sensory experience. Color structure united with a graphic-time structure is comparable to the relationship

between orchestration and theme structure of a musical composition: the two contribute to a unified whole. Just as orchestration provides the symphonic composer with a large textural vocabulary with which he may build richly or thinly to his structural needs, so it is with color for the audio-visual-music composer.

The fallacy of mechanically translating previously composed music into some visual "equivalent" is established repeatedly in critical writings on the subject. A more fruitful, less mechanistic approach is possible today, for truly creative possibilities arise when the image structure dictates or "inspires" sound structure and vice versa, or when they are simultaneous conceptions. This obviously is best realized when both parts have common creative origins.

This unified creative potential is available today, even for the artist, as sound-track writing or synthesizing devices, manageable by one person, appear on the horizon along with simplified animation techniques.

The generally accepted assumption that the cinema must be an industrial-cooperative art, is least likely to be so with audio-visual-music. The individual artist plays a role here as freely as if he were a painter.

The artist's access to affordable equipment is assured. Amateur cine equipment compares well in quality today with that of the industry. There already exist small enterprises that are prepared to supply special processing, sound recording and duplicating services to small-scale limited-budget filmmakers. The remaining technological problem for the independent artist/composer is somehow to secure final perfection of these new means.

The role that television can play in the development of audio-visual-music probably cannot be underestimated. Undoubtedly the most striking quality of the television program is its intense realism; the realism of spot news and spontaneous programs of all sorts. But the by-product of this very spontaneity is disorganization – structurelessness as compared with music. It will have to be dealt with in much the same manner as radio deals with structureless programming, by ample use of music. The so-called music bridge and incidental music of radio serves this purpose. The relatively unorganized spontaneous portions of the radio program are carefully sandwiched between periods of music. Even though it had the enormous accumulation of all western civilization's music

to draw upon, radio found it necessary to employ composers to supply radio's specific needs.

It is safe to assume that television will discover a similar need for an audio-visual equivalent to radio's music bridge. The need will begin a search beyond temporary solutions that are motivated by expediency. The artist with a sense of the deeper meaning of structure can make the distinction between a temporary solution and a structural solution. Technological trinkets in the form of kaleidescopes and other mechanical-optical devices which will fill the television screen with arbitrary pattern and are related to music mechanically, if at all, are certainly not the "structural" solution to providing graphic and musical order to television.

Television, insofar as it performs as an integral part of the new times and its society, will not only employ hours of audio-visual-music but it will perform individual works of the contemporary composers.

Audio-Visual Music and Program Notes 1946

This artists' statement and program notes for *Five Film Exercises* were prepared for the catalogue of the first *Art in Cinema* festival at the San Francisco Museum of Art (Fall, 1946) – an historic occasion on which a whole range of European avant-garde films from the Museum of Modern Art in New York were screened beside new work by young American filmmakers. This festival became an annual event lasting into the 50s, and this showcasing of classic and new work in a museum setting provided the catalyst for young painters like Harry Smith and Jordan Belson to turn to film and their own personal versions of "audio-visual music."

The statement of John and James Whitney exhibits a mature understanding of their art in the context of modern painting, and reaffirms their healthy attitude toward "the machine" as a potential instrument of art rather than a necessary menace to traditional handmade art product. The notes on the *Exercises* demonstrate clearly how carefully those films were planned and executed according to principles of advanced music and visual theory. – *W. M.*

Section One:

Each individual who has identified himself with the abstract film medium has begun from scratch and devised every detail of his technical means. Inevitably, form under this circumstance has been preeminently interrelated with technique. Form is weak or it flowers just so well as the means are integrated. The perfection of means, however, does not proceed along a simple forward path of progress, because this art is not a science with a rationale more than any other. And it is actually a very new thing that so much technology must be brought to bear upon an art form as it is in the field of the cinema. Perhaps the abstract film can become the freest and the most significant art form of the cinema. But also, it will be the one most involved in machine technology, an art fundamentally related to the machine.

In our work, we have continuously sought an equilibrium between

technical limitations and creative freedom. We have partially achieved it, lost it again, and now search for it once more at a higher level. Our first film made with an optical-printer but without sound, is a case in point; the equipment and the state of our general technique determined a set of limitations which have never since been so circumscribed. Yet within those limitations was found an area of freedom open to creative manipulation which has never again been so vast. This film rapidly acquired unity and simplicity.

With our expanded means, including sound, today we endeavor to reestablish that equilibrium. This, we believe, has become possible as we accept the technical means at our disposal as adequate and proceed to widen the area of freedom within discovered and accepted limitations. The films produced over the five-year period since our first, seldom have been completed before their value to us as experiments were negated by new experiments following a new approach to form and with altered and sometimes improved equipment. Thus, they frequently manifest one technical quality or another that is subtly out of order with their formal organization. Still, they are better described as exercises than experiments, for they are rehearsals for a species of audio-visual performances that we can very well visualize now.

Section Two:

It is a commonplace to note that film and sound today have become a permanent unity. We are attracted by the prospects of an idiom as unified, bi-sensorially, as the sound film can be.

Naturally, we have wanted to avoid weakening that unity, which would be the very essence of an abstract film medium.

It occurred to us that an audience could bring with it its own disunifying distractions in the form of numerous past associations and preconceptions were we to use previously composed music in relation to our own abstract image compositions. We, therefore, tried the simplest, least common, primitive music we could find. But another source for disunity became apparent. In this case, the dominant source of distraction was a contradiction between the origins (the players, instruments, time, place, etc.) of this kind of music and animated image.

Thereafter, little thought was given to any other consideration than to

search for a method of creating our own sound by some means near as possible to the image animation process, technically and in spirit.

Section Three:
The sound track of all our films to date was created synthetically by the device which came into being as a result of these conclusions. Without attempting to describe it in detail here,* its principle resembles less a musical instrument than certain devices used for charting the rise and fall of ocean waves. Pendulums instead of waves create the ebb and flow movement. This motion is greatly demagnified and registered on a narrow space of the motion picture film provided for a sound track. The patterns themselves generate tones in the sound projector. The instrument has a selection of some thirty pendulums adjusted in frequency relationship to each other so as to form a scale. They can be swung singly or in any combination.

We value the instrument despite certain distinct limitations for an assortment of reasons. An immediate practical one is that it as much as provides us with a means where otherwise there would be none at all. Sound recording of original music even at the 16 mm. scale is prohibitively expensive and presents enormous difficulties for the amateur.

Some other reasons have to do with adaptability of the instrument to our purposes. In composing the sound, we seek to exploit a spatial quality characteristic of the instrument which reinforces that effect of movement in space which we seek to achieve in the image. Since both image and sound can be time scored to fractions of a single motion picture frame, there is opened a new field of audio-visual rhythmic possibilities. The quality of the sound evokes no strong image distraction such as was observed in other music. Consequently, the sound is easily integrated with the image. The scale of the instrument is adjustable to any intervals we may choose including quarter tones and smaller. This permits use of graduated ascending or descending tonal series. They correspond in quality of feeling and variability to certain types of image series, such as, for example, an enlarging or diminishing shape, an

* A description can be found in Leon Becker's article "Synthetic Sound and Abstract Image" *Hollywood Quarterly*, V. 1, #1 (October, 1945) pp. 95–96.

ascending or descending shape, or a color series.

In concluding this section it should be observed that there is for us perhaps more personal freedom than is possible in any other motion picture field today. Our sound and image technique provide a complete means accessible to one creator. We believe in the future of the abstract film medium as one differing from the others in that it demands none of the large scale collaboration typical in present motion picture fields.

Section Four:

We seek to extend certain principles which have evolved over the past forty years by the work and thought of such men as Marcel Duchamp and Piet Mondrian.

During this time, in painting, spatial limitations of the particular, human, real world have generally given way to a concern with a conceptual simultaneity of space-time. Mondrian sought "a truer vision of reality" by destroying the particular of representation, thus liberating space and form in terms of equilibrium.* By a mechanical destruction of the particular we believe it possible to approach anew this problem. We seek a new equilibrium – an equilibrium on a temporal frame as in music. And we seek a balance of contrasting plastic **movements.**

Obviously Western Art forms have been no less determined and limited by their accepted creative means than our work is limited and its character is determined by our mechanical means. Our very realm of creative action is implicit in the machine. Emphasis is necessarily upon a more objective approach to creative activity. More universal. Less particular. More so by virtue of the inherent impersonal attribute of the machine. We discern a creative advantage here similar to that deliberately sought after by both Mondrian and Duchamp, however opposed their respective points of view; Duchamp, an anti-artist, and Mondrian, seeking a purity of plastic means.

But the machine is yet a poorly integrated, clumsily handled invention else man would not be face to face with his destiny by it today. Personal contact with new creative fields by way of the machine would hardly be worth struggling after were it not for the tremendous variety of

* *Plastic Art and Pure Plastic Art*, New York, 1945.

new clay to be found there, its universality and its close kinship with modern experience.

Our animating and sound producing devices do not respond to our touch as a musical instrument responds to the virtuoso. Aside from our own admitted inexperience there are clear-cut historical reasons for this. The devices of art and music which have made Western Art forms possible, originated in antiquity and have evolved slowly paralleling the life of that culture. The introduction of the machine in such proportions as has taken place only in this century constitutes a quantitative change effecting a distinct qualitative revolution. The motion picture camera is no more an improved paint brush than our sound track device is an improved musical instrument.

It is our opinion that the work and ideas of Marcel Duchamp with his underlying principles, against hand painting, and, a studied exploitation of the mechanisms of chance, make a significant esthetic contribution to the advancement of this "qualitative revolution." Perhaps his concept of irony provides a clue to the whole future of machine realized art. He defines his meaning of irony as "...a playful way of accepting something. Mine is the irony of indifference. It is a meta-irony."* Our own experience has been that this corresponds very closely to the correct philosophical disposition by which the resources of the machine may be accepted and employed.

Notes on the "Five Abstract Film Exercises"

by John and James Whitney

First Sound Film, Completed Fall 1943:

Begins with a three-beat announcement, drawn out in time, which thereafter serves as an imageless transition figure dividing the sections of the film. Each new return of this figure is condensed more and more in time. Finally it is used in reverse to conclude the film. There are four sections constructed from the same three thematic ideas. They depend

* Quoted in Harriet and Sidney Janis. "Marcel Duchamp: Anti-Artist," *View*, Series 5, #1 (March, 1945), p. 23.

upon subtle alterations of color and juxtaposition of these three distinct themes for contrast.

This film was produced entirely by manipulation of paper cutouts and shot at regular motion picture camera speed instead of hand-animating one frame at a time. The entire film, two hundred feet in length, was constructed from an economical twelve feet of original image material.

Fragments, Spring 1944: These two very short fragments were also made from paper cutouts. At this time we were developing a means of controlling this procedure with the use of pantographs. While we were satisfied with the correlation of sound and image, progress with the material had begun to lag far behind our ideas. These two were left unfinished in order to begin the films which follow.

Fourth Film, Completed Spring 1944: Entire film divided into four consecutive chosen approaches, the fourth being a section partially devoted to a reiteration and extension of the material of the first and second sections.

Section One: Movement used primarily to achieve spatial depth. An attempt is made to delay sound in a proportional relationship to the depth or distance of its corresponding image in the screen space, that is, a near image is heard sooner than one in the distance. Having determined the distant and near extremes of the visual image, this screen space is assigned a tonal interval. The sound then moves along a melodic line in continuous glissando back and forth, slowing down as it approaches its point of alteration in direction. The line would resemble slightly a diminishing spiral as viewed on a flat plane from the side. This section concludes with a frontal assault of all imagery with an interacting tonal accent.

Section Two: Consists of four short subjects in natural sequence. They are treated to a development in terms alternately of contraction and expansion or halving and doubling of their rhythm. Sound and visual elements are held in strict synchronization. Color is directed through a blue to green dynamic organization.

Section Three: A 15-second visual sequence is begun every five seconds, after the fashion of canon form in music. This constitutes the leading

idea, a development of which is extended into three different repetitions. This section is built upon the establishment of complex tonal masses which oppose complex image masses. The durations of each are progressively shortened. The image masses are progressively simplified and their spatial movement increasingly rapid.
Section Four: Begins with a statement in sound and image which at its conclusion is inverted and retrogresses to its beginning. An enlarged repetition of this leads to the reiterative conclusion of the film.

Fifth Film, Completed Spring 1944: Opens with a short canonical statement of a theme upon which the entire film is constructed. Followed by a rhythmical treatment of the beginning and ending images of this theme in alternation. This passage progresses by a quickening of rhythm, increasing in complexity and color fluctuation. After a complete repeat of this, there follows a deliberate use of the original theme in a canon form, slow and with sound counterpart also in canon. The sound thereafter is entirely constructed upon the material derived from this section. The canon is repeated in contrasting variation by means of color and leads into a further development of the early rhythmical ideas on beginning and ending images.

A second section begins after a brief pause. Here an attempt is made to pose the same image theme of the first section in deep film screen space. As the ending image recedes after an accented frontal flash onto the screen it unfolds itself repeatedly, leaving the receding image to continue on smaller and smaller. The entire section consists of variations on this idea and further development of the rhythmical ending image ideas which recur in the first section.

(From technical notes, written in 1947, which were also published in *Art in Cinema,* 1947.)

Appendix

Moving Pictures and Electronic Music 1959

This article was written in 1959 for Karlheinz Stockhausen and Herbert Eimert's serial music journal *die Reihe*, where it was published in Vienna in a German translation. Five years later, an English edition of that issue appeared in the U.S. with this article retranslated from the German text back into English. Needless to say, some humorous and embarrassing passages resulted. The text printed here is John Whitney's original English version, not a translation. It provides the fullest description of the pioneer pendulum "electronic" music which the Whitney brothers were creating before magnetic tape made possible what we know as electronic music today. – *W. M.*

The year 1940 marks the beginning of this short history. It might be called a piece of Western frontier history for there are signs of a frontier in it – in one sense – and there is a note of isolation.

Stimulated by the avant-garde filmmakers of France and Germany of the early twenties, I began alone and was soon joined by my brother James, making what were then called abstract films. My point of view was that of a composer; my brother was a painter. I had been casually introduced to the Schoenberg twelve-tone principals by friends in Paris a year earlier. Other than this brief exposure to a modern trend of music composition, we had Ernst Krenek's pamphlet, *Studies in Counterpart,* plus recorded music to listen to, including Pierrot Lunaire; the pieces for piano Opus 19 and the Opus 37 String Quartet of Arnold Schoenberg; also Alban Berg's Lyric Suite and violin concerto. It may be said that we were more broadly acquainted with the temper and spirit of modern art, including the Bauhaus in Germany.

As unprecedented comparatively as our art was, the tools were also new or actually awaiting invention. We looked upon toolmaking as a natural aspect of our creative occupation. We treated this facet of endeavor

with respect, designing with care even the appearance of an instrument, for example. We accepted, of course, the probability that formal considerations would somehow evolve as a result of an interactive play between ourselves and the character of these tools. And to bear this out, it will be seen that certain formal ideas did come directly from the subsonic approach that we found for producing the sound of our films.

Our subsonic sound instrument consisted of a series of pendulums linked mechanically to an optical wedge. The function of the optical wedge was the same as that of the typical light valve of standard optical motion picture sound recorders. No audible sound was generated by the instrument. Instead, an optical sound track of standard dimensions was synthetically exposed onto film which after processing could be played back with a standard motion picture projector.

The pendulum, whose natural sinusoidal oscillation is fixed by the location and size of its weight, constituted our limited source of tone generation. Though the frequency range of our set of pendulums extended only somewhat over four octaves, from a base frequency of one second, the extremely slow drive mechanism which passed the raw film over the light slit at the recording optics was also variable over a range of several octaves. By changing the drive speed the pendulums as a group could be shifted up or down the frequency spectrum.

The pendulums were individually tunable. We soon found that we could watch the comparatively slow swing of these pendulums and adjust their weights to any of the common interval relationships. For example, it was easy to count two strokes of one pendulum and adjust another to make exactly three strokes in the same period; both pendulums swinging past a nodal point in unison every 2nd and 3rd oscillation respectively. This tuning would sound the interval of the 5th. Due to the design of the mechanical linkage any number of pendulums could be played simultaneously. The linkage in effect "mixes" sinusoidal oscillations without undue distortion.

Composing for an instrument with the thinness of tone spectra as ours had determined a need to exploit our resources with ingenuity and to their fullest. There were other reasons, of course, but this sense of a need for extreme economy motivated avoiding any tuning of the pendulum set to a "scale" that would not be used in its entirety.

As a formal point, then, we chose to tune the instrument to a serial row that would be different with each composition. This serial row might be played out sequentially depending upon horizontal considerations of the music structure. Also, all or any part of the row could be played simultaneously. This way a vertical note mixture (not a chord) would be produced, the timbre or components of which could be continuously varied by bringing in and out different groupings of frequencies. The attack and decay of the tones of the instrument could be controlled by literally starting and stopping the pendulums either abruptly or slowly. Vertical or horizontal aspects of a composition were thus structurally interrelated in a peculiarly meaningful way.

Furthermore, since the drive speed was so slow (sometimes as slow as one motion picture frame in sixty seconds) it was possible to start and stop a sequence of perhaps 20 pendulums within one frame; that is, within one twenty-fourth part of a second at playback speed. It was even possible to play a small pendulum or to correlate in different ways various (literally counted by eye) numerical orderings of cycles. We soon observed that microclusters of transient tone sequences produced this way presented very rewarding compositional possibilities. These tight clusters produced distinctive timbres; yet if the elements of the groups were progressively lengthened in duration they became audible as discrete note sequences of rhythmic order. We found that here was established a continuum from rhythm to pitch. Our instrument could encompass the range. It became a structural foundation of our music compositions.

There is one other aspect of the sound techniques that deserves mention before proceeding to a discussion of image and space concepts. At an early point in our filmmaking a method was devised to record four channels of sound. This was done primarily to facilitate recordings of structures of a degree of complexity otherwise physically impossible to perform even at the extremely slow recording rate we employed. Second, third, and fourth records were exposed on the sound track at different recording speeds according to our notational system.

In this way it became possible to conceive still another facet of the interrelationship of time and pitch. The act of performing on this instrument – essentially starting and stopping the pendulums and controlling

their amplitude – could be governed by the instrument time (i.e., frame speed) or by the constant clock time. Assuming a given clock-time interval, then pitch and duration became a function of the drive speed of the machine, i.e., the recording rate. Thus pitch ratios and time ratios were drawn still closer together and became more accessible as compositional elements. (Indeed the continuum of pitch, timbre, and rhythm relationships of this machine was unprecedented in Western musical resources and anticipates the application of computer technology to musical composition. Our *Five Abstract Film Exercises* were made under these auspices – note added in 1973 by John Whitney.)

Our activities were not alone musical since our first interest had been to compose abstract graphic compositions with a time structure as in music. Before the above musical researches were begun, we had made several silent abstract films.

The earliest film to be completed consisted of 24 variations upon a graphic matrix. This matrix was given action potential by an extremely simple animation idea. The illustration (fig. 1) shows a diagram of the complex matrix which was actually never revealed on film in this static

Figure 1

configuration. This matrix was broken down as shown in fig. 2 and produced with an air brush. The forms of the matrix served as a simple

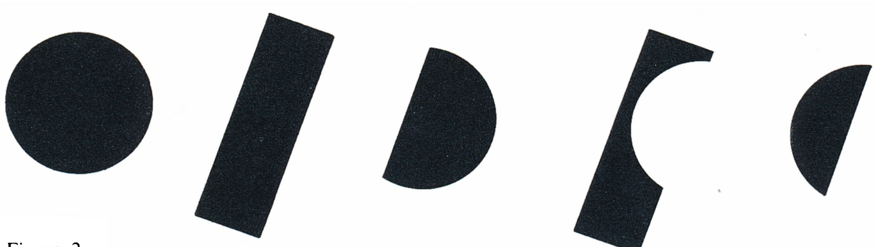


Figure 2

positive and negative stencil as shown in fig. 3. The resulting animation cards with phases and movement were then photographed in sequence onto black-and-white film.

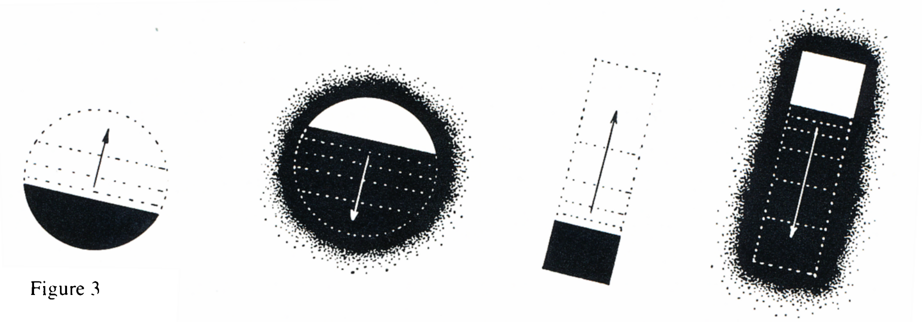


Figure 3

This film strip was in fact one of perhaps many possible serial permutations from the original total static matrix. We devised an optical printer in which this film strip could be rephotographed onto color film using color filters; either in normal direction or retrogression, right side up or inverted, or mirrored. Graphically here was a parallel to the transpositions and inversions and retrogressions of the twelve-tone technique.

Seeing this short film back from the laboratory for the first time, my brother and I experienced the most gratifying stimulation of our entire filmmaking activities. Within its extreme limitations, here was a generous confirmation of our compositional principles; the permutability of the simple graphic material permitted a great variety of compositional structure. We were soon engaged in elaborations upon the matrix ideas which presupposed some form of serial permutation to be juxtaposed dynamically against itself by retrogression, inversion, and mirroring.

The following years were a time of continuous discovery of steps toward a more fundamental graphic element. The static matrix ideas were modified then supplanted by other discoveries.

ASID Talk and Belgian Competition 1963

This talk delivered at the Catalina Design Conference in 1962 affirms the position that "motion graphics" is a complex new field which can only be exploited properly through the sensitive use of technological instruments – a stand against the intuitive handmade films of the music-illustration animators, and a stand in favor of the "gageteers" which these animators (especially Fischinger) had spoken out against, feeling that machinery would hamper artistic instincts or substitute mechanical regularity for nuance and mystery.

In his assessment of the 1963 Knokke competition (originally published in the same issue of *Film Culture*), Whitney announces clearly the complementary principle which will govern the aesthetics of his later work: the essence of the time/movement/development factor in motion graphics must be consistent "permutations" of the basic material, not just a random collection of diverse effects strung together to musical accompaniment. – *W. M.*

A.S.I.D. Talk-Design Conference, Catalina, 1962

When a film title in the tradition that Saul Bass has done so much to establish, has interesting articulation, it usually succeeds as a title. On the other hand, if it is lacking effective motion or articulation it might as well have been a book jacket, at best, perhaps like those that Alvin Lustig made. This matter of articulation is what I refer to as **Motion Graphics** and it is distinctly a new problem in the field of design; so little explored in fact that designers must approach it with caution and the proper sense of adventure. Film titles have been sold to clients; sold, approved and paid for, that must have looked superb in the storyboard layouts. But the storyboard would be at best a series of static drawings ostensibly to suggest or imply the motion that was conceived. If in production, this action is not realized, or was unimaginative to begin with, very, very impressive storyboards from the point of view of still graphic design may still be **still** graphic design when they reach the screen – we say the work is not dynamic. It may be good graphics – it is not good **Motion Graphics.**

Now how does one delineate motion graphics? Abstract filmmakers have been pondering this question – stabbing at it in the dark of projection rooms since the early twenties. Man Ray achieved a brief triumph in this direction forty years ago. He simply stood starched white collars on end on a phonograph turntable (a trick in itself) and filmed the turning spiraling white shapes against a black background. The camera and film was simply given to him. Man Ray showed this film to slightly delirious gatherings of dadaist sports while a phonograph in the theatre played the "Skater's Waltz." Truly this was a triumphant moment of motion graphics, predating sound motion pictures.

About every abstract filmmaker since, who has had his own modest success, has come by it with almost as much fortuitousness. That is putting it rather crudely; but it is so that some have achieved high moments on film by swirling a mixture of incompatible paints in a barrel, or scratching, biting, crayoning and otherwise torturing raw motion picture film without using a camera at all. Others have hung other people's sculpture on invisible strings and let them turn in front of a camera, still others have filled space with wads of colored plastic and such and set spotlights moving and filmed the reflections and refractions moving on the wall.

I have listed this hodgepodge of techniques to emphasize that if you want to compose an abstract film you just can't pick up any thread of tradition winding back into the past. And you can't walk into a store and buy an instrument that plays abstract design. A camera is of no use in this respect; more than a phonograph would be of use to a composer. Abstract filmmaking then (the pure art of motion graphics as opposed to film titles, which is an application of art) is a **new** art which demands complex tools.

Now to digress a moment: Before the war, I contracted what at that time was a common fever to make film "Symphonies." Joris Ivens and others made these films, and always called them "Symphonies," (just why – I couldn't say since they were always such little films – hardly a movement of a Symphony). I found that if you go out with a motion picture camera and shoot nature, you'll be surprised how little real **action** you can get. Especially if you know as anyone should that Slavko Vorkapich had already shot all the ocean and clouds that need shooting

for all time – ever! And Ivens had already shot too many rain drops and riverlets. "What else on Earth moves?" you ask yourself. Nature, all in all presents a surprisingly static image to the cameraman who wants to make "Symphonies," abstract ones, that is, where animals and humans don't fit.

I have brought this up only to make the following ironic observations that our concepts of nature and the universe have become dynamic. We know in this Non-Aristotelian age (to borrow a phrase) that time and motion or, time/motion make the scene today.

Now I might quote here from Gyorgy Kepes's *The New Landscape* or other books of art philosophy. Instead, I need only go to the grocery store and pick up a copy of Harper's and read to you what Sir Kenneth Clark of the London National Gallery has to say.* "Art and science are not, as used to be supposed, two contrary activities, but draw on many of the same capacities of the human mind.... Artist and scientist alike are trying to give concrete form to dimly apprehended ideas." Sir Kenneth quotes Dr. Bronowski as saying "All science is the search for unity in hidden likeness, and the starting point is an **image** because then the unity is before our mind's eye." He gives us the example of Copernicus's notion of the solar system which was inspired by the old astrological image of man with the signs of the zodiac distributed about his body. Then Sir Kenneth continues: "Our Scientists are no longer as anthropomorphic as that; but they still depend on **humanly comprehensible images,** and the valid symbols of our time, invented to embody some scientific truth, have taken root in the popular imagination." Here in a nutshell is background for abstract art. But notice that here we can also perceive the timely validity of the abstract image in motion. The nuclear scientist will agree readily that he is concerned with dimly apprehended ideas of forces and energies and particles in motion. His artist contemporary should (and does not) have any great facility to create image in motion. To repeat: our concepts of the universe have become overwhelmingly dynamic. The valid symbols of our time possess this dynamism implicit in them, and I am concerned with **motion graphics** because I feel the need for explicit **motion** in **graphics** as against the implicit motion

*"Art and Society." *Harper's*, v. 233 (August, 1961) p. 81.

of the painter's canvas.

The search for a viable system of motion graphics has ranged far and wide among abstract filmmakers. Here and there we have had it on our conscience that we had become too much involved in mere technology. It has been a sensitive point with some to hear a challenge, that goes like this: "If you are so damned interested in this kind of film why don't you make films, instead of messing around with all the gadgetry." For better or worse, I have resolved this question in my own mind. I decided last year to engage in the construction of bigger and more elaborate gadgets.

My point of departure would seem to be at the crossroads where computer designers abandoned mechanics altogether and introduced electronics. This turn in itself was fortuitous, since it made obsolete a $33,000 device which was then placed in surplus which I can now buy for less than $200. I am told it is one of the more sophisticated mechanical analogue computers of specialized function that were produced during the last war. It happens to be an "Anti-Aircraft Gun Director." It contains a beautiful network of cams that are variable and made an exceedingly versatile two dimensional coordinate design instrument – with a few alterations. I have not studied the history of cam linkage deeply, yet it is interesting to observe again and again all the way back through the 18th Century that cams have been assembled variously to trace intriguing designs on paper. Yet through all this time no one seems to have found much use for these designs other than to decorate gilt edge bonds and currency. It seems to be characteristic of this time, however, that innumerable so-called blind alleys submerged by industrialization revolutions are eventually rediscovered. I think of Art Nouveau glass or Thonet bentwood furniture.

Who knows — perhaps the abandoned cam may have something new to offer as a rediscovery. My experience would seem to bear this out. I presently earn a living using these devices in films and also in architectural decorations. This may account somewhat for my rash decision to build more versatile cam machines.

At any rate, I am trying to erect a total motion graphic system. If I were a composer like Arnold Schoenberg, at least I might arrive at a system without having to invent the symphony orchestra in order to hear my system applied. Yet that advantage already has been lost to many

modern composers. Karlheinz Stockhausen must penetrate deeply into the field of technical invention if he persists with electronic music. So I am not alone when I find that if I **must** make a system, I must also simultaneously invent machines.

Now let me try to explain some of the philosophy of a "gadgeteer" and I will be through:

In the first place we need only look at the twelve-tone scale of the alphabet to realize what versatility is possible from a permutational system. So I am looking for a permutational system of graphics. The first of the little silent films shown here tonight is an example of rudimentary, permutational graphics. The entire film was made from one rectangle and one circle in one position in the film frame. All other positions of the circle and rectangle are achieved by inversion and mirroring the film strip from the original positions. The action too is a serial configuration that undergoes permutation by reverse direction, skip printing etc.

But this little film suffers from limitations which suggests that as a system of composing it could be soon exhausted of fresh possibilities and thus die. So the second requirement for a system of graphics might state that it must be viable. Somehow the ideal system must offer resistance so that with every new approach the composer finds before him a challenge.

For example, risking oversimplication of history, it may be said that after a few hundred years during which Western musical culture evolved, this challenge in music composition has come to resemble nothing so much as a tidy problem in mathematics. Rules have accumulated in profusion and the challenge is there as any first year harmony student will agree.

Finally, I am looking for a graphic system that will produce simplicity and complexity at one and the same time. This would be hard to explain in terms of graphics. Another meaning of the word "articulate" refers to speech; to enunciate distinctly. Speech poorly articulated is garbled speech. The communication specialists refer to all elements in a message that do not contribute to the message as noise. Now for the purely sensuous appeal of texture and pattern there is need for complexity in motion graphics. But simultaneously there is need for simplicity for the sake of articulation and communication. Still there must be no

noise in the system.

Now what constitutes noise if the message happens to be a music composition? Of course, it might be a jet passing overhead or hum in the amplifier. But it could be clumsy orchestration in which the clarity of the musical ideas have been simply spoiled with unnecessary doubling of voices and generally inept composing. This too is noise, I think, by the communications definition.

Inept and unnecessary embellishment also spoil the message in graphic art, obviously. Yet judicious use of texture and pattern can be an aid to the message. In motion graphics the problem is compounded by the fact that all texture if it is static, looks static. There is a disparity between action and any static element in the frame that always seems irreconcilable and therefore contributes only noise. The problem of texture, familiar to the animator, is only magnified here. Thus for the sake of unity and clarity of the message, action in terms of the total frame must be considered. So, the third feature of my system seeks to involve the whole frame in a species of multiplex action that still must be simple and unified in its total effect.

Now a word about the film that is to follow. It is a catalog of some effects I have begun to explore with my latest equipment. I wish only to say that it consists of film which I am making by the yard these days. One piece is spliced to the next without any deep logic of sequence.

I would not want to imply that any of these lofty ideals of which I have been speaking are realized in this film; or are even near realization.

An Abstract Filmmaker's View of the Belgium Experimental Film Competition (1963) and All

Film competitions of this sort are notoriously tiresome affairs. Some filmmakers are downright cruel – if the well-being of their audience is a matter of concern to them in the least. So experienced competition-goers learn to walk out early. I observed that they develop a precise sensitivity to each film's tedium quotient and they often leave in sizeable numbers a few seconds after the titles. They even behave this badly when the abstract films come on. Indeed, at Knokke the film which may have won the loudest objections from the smallest audience was an abstract film. This general category did not however receive in total the most numer-

ous demonstrations of audience distaste. Perhaps that is only because there were so very few abstract films in competition.

I had gone all the way to Belgium to get some perspective on the world state of abstract filmmaking. Now the big question seemed to be: does the species really exist at all in the contemporary world of cinema? For the few films which sensibly fit into that area by definition certainly presented nothing that was not more imaginatively realized in 1958 or even in 1949. Were I not somewhat prepared for this and predisposed to regard any evidence of decline quite differently than one might expect, I'd have been truly discouraged. More about that optimistic disposition later.

There is something illogical about the pattern of growth (or decline) one sees if for example he merely reviews in sequence the entries and prize winners of the three Belgium Experimental Film Competitions. The 1949 prize winners were predominantly abstract films and I believe the view was rather widespread then that the winning films were as much a foretaste of the future as they were themselves any great achievement of film art. There was a hint by 1958 that this future was not materializing.

If we compare the atmosphere of the 1949 competition in Belgium with another time and place, namely the Cologne 1951 festival of experimental electronic music, similarities as to the promise of the future are obvious. But here the comparison ends. For electronic music activities have since proliferated with endowed, even state sponsored centers of study spread over the world from Japan to South America, and already new composers and their work are engaging world wide attention. Nothing to compare with this busy state of affairs has dignified abstract filmmaking.

Yet the **idea** of this kind of film art, I must insist, was as broadly accepted as the idea of a new music. Certainly many who were initially challenged by the above idea of motion graphics have long since abandoned it to indifference or commercial live-action film. Some others simply did not buy motion graphics in the first place, and they can practically sing in chorus today, "I told you so!" But these cynical, pessimistic taunters are few in number compared to the other faction – those who did not make motion graphic films themselves and those who generally accepted motion graphics as a valid, promising concept.

As a semi-professional actually trading upon this same beleaguered idea, I was obliged at Knokke to try my best to serve as professional apologist to explain first, that all is not lost, and next, to attempt to express a broader viewpoint on this whole subject.

Look back for a moment as I did. Len Lye, McLaren and Fischinger are perhaps the great innovators and they can each show you films that represent at least second, possibly third generations beyond their original inventions in film. A few other filmmakers can show singular successes which constitute their only sortie into the rarified air of abstract cinema. Not one individual can be named who has made a successful career for himself strictly within this specialized field.

It would be difficult to explain why each filmmaker's effort in a given technique seems almost to exhaust that technique on his first or second try. But this characterizes abstract filmmaking from its beginnings to the present day. Then also, about every filmmaker since Man Ray who has had his own modest success, has come by it with a degree of fortuitousness that is in itself quite disconcerting. Composers today are busy exploring all avenues of chance in music composition, but this is no strain and far less disconcerting for the inheritors of a tradition that is rather overblown with intellectualism and excessive mathematical orderings. On the other hand it must be slightly unnerving for the filmmaker to discover in a moment of truth that his best audio-visual interrelationships have been mostly fortuitous, his most striking graphics, purely accidental.

The employment of cinemascope plus color in one or two abstract films in the Belgium competition was effective in generating a lush sensuous experience for the eye. One might wish however that something more satisfying could come from all that rich color imagery. It was as if each square yard of that huge screen in front of us contained delightful graphics in motion but all of it was operating at cross pusposes. Or it was as if we had before us an orchestra on the stage consisting of expert musicians playing superb musical instruments but that each musician was determined to negate any purpose of the other. A situation again which might be of interest to the composer for reasons that transcend any mere protest reaction against the well-known ensemble achievements of the modern orchestra. It would be an auditory situation approximating

the useful musicological concept of white noise: the full auditory range sounding at once. Of course this is only an approximation because the true visual representation of white sound would simply be a white screen. But the parallel between a stage full of musicians playing at cross purposes and a screen covered with action and texture and rich color is rather painfully exact. In both cases one soon longs to see (or hear) something more in terms of form register by way of all this rich sonority – audio or visual.

These doleful reflections did not add any to my contentment with the few abstract films I saw in Belgium at the close of 1963. Nor do they now help me in the task I have undertaken with this writing.

So what is astir to be hopeful about? What argument shall one take as apologist?

For one thing, isn't it cozy to have reached bottom from which famous position there is no other direction but up? I have observed also that filmmakers do not as a group show any serious tendency to repeat themselves or anybody else. (Is this a concomitant of the forementioned tendency to exhaust each new technique after one or two trials?) Or perhaps the past can be viewed as a kind of catharsis; premature to be sure, for such a young thing, but nevertheless much needed to clear the way for: – who knows?

Here I cannot help but add a digression as much as anything to express my concern with all areas of filmmaking such as we viewed at Knokke. Perhaps the above "expiatory" viewpoint can be applied pointedly to the "new American cinema." Now that such films have been made once, maybe no one need make another *Flaming Creatures* or "Twice a Dog Star Man Triangular." O.K.; we are purged. And hopefully the only way onward is now, somehow, in a new direction.

But these are only negative comments and above all I wish to say something very positive as to how one may regard matters as they are.

Concurrent with the Experimental Film Competition was a gallery show of the work of the Group de Recherche d'Art Visuel. The classical distinctions between painting and sculpture were repeatedly breached in this show. But of more interest to the filmmaker, were the distinctions between motion in these works and cinema. Many of their three dimensional productions included integrated light projection systems. With these they have literally created cinema in an art gallery. Judging the general reaction to this show I came away with the distinct impression

that disciplined exploration of the simplest graphic elements in this modern time is still treated as a kind of exotic new frontier. One only needed to remember that the entire history of western musical culture is based upon the simplest principles of permutation to start a chain of reflections as to why only now at the late time we have begun seriously to experiment with the possibilities of motion and **permutation** within the disciplines of the graphic arts. But the point is, they are begun. And with this particular group the point of departure is far, far beyond the previous researches of the Bauhaus and the neo-plasticians.

Also there were concerts of contemporary music and symposia in which the immediate practicality of the use of the computer for generating music were discussed. The nonsense bugaboo about the "mechanistic inhumanity" of the "thinking machine" was dispatched readily and serious discussion that followed appraised favorably the imminence of applications of computer technology as a new instrumentation at the service of the composer. Then in Paris and New York I saw more, pointing to new avenues opening between artist and this fantastic new instrumentation.

It all relates, and adds up to a view of a world that is rapidly moving toward the obsolescence of practically the whole technology of motion picture making, for motion graphics especially. So the abstract film-maker is destined to become indeed a colossal figmentary anachronism. Of course he too has existed only to be purged. His visual achievements, small as they are, may not be forgotten. But his aspiration will one day soon, it is to be hoped, come to fruition by means of a marvelously more facile instrumentation linked to the computer and cathode image systems.

Personally, I am optimistically committed to this point of view. I have employed rather elaborate automated design mechanisms which are derived from a recent phase in the growth of computer technology. Just as computer techniques are evolving along a somewhat logical pattern toward greater refinement, it is my assumption that new graphic as well as musical possibilities should likewise evolve. At present my equipment is supplemental to the motion picture camera which now serves only the recording or memory function. But all my research effort is oriented in anticipation of a fuller employment of modern computer systems dispensing with the camera altogether.

Future computer systems will certainly transform graphic and musical instrumentations in ways that are still unimaginable. But among the

ends in view is the capacity to modulate complex design fields in time, much as musical chords smoothly succeed one another. That this has not been possible by any trick of camera or animation art will serve to suggest the plight of abstract cinema till now. Thus it is precisely the anachronistic quality of the story of abstract film making that should illustrate best the need as well as the inevitability of future creative applications of computer technology. Stated bluntly, the abstract cinema (so-called) awaits the computer to be born.

I have always been disposed to view abstract filmmaking as the truly unique time art of the dawning age of complex instrumentation which so threatens and at the same time promises to revolutionize global social and cultural patterns. This point of view was clarified a little at the film competition. It takes a hectic and wonderful week in a little known Belgian seacoast resort, looking at quite an assortment of failures, to get a bright idea of what new is going on.

Aspen Design Conference 1967

The 17th International Aspen Design Conference was devoted to the theme "Order and Disorder." John Whitney's comments on this topic give him the chance to discuss the issue of the Random *vs.* the Structured, and how pioneers in the new fields of electronic music and electronic imagery must deal with them *vis a vis* the absence of tradition and the presence of "unlimited" possibilities. – *W. M.*

Let's consider the use of chance in music composition. Computers can be used as random number generators, but when you pin somebody down about this, you find they are not random at all; computers generate random numbers by some system or another. Get a mathematician to level with you and randomness begins to look like a theoretical concept without practical reality. So random and order, chance and disorder become linguistic exercises that fit differently into different disciplines like one man's poison.

Looking backward into music history, the part chance played seemed to hinge on such matters as: "Does the bassoonist have a cold or not?" Today we are looking at a rather alarming discontinuity in that history. For awhile it looked as if the magnetic tape medium was the cause of all this discontinuity, but now we know it is really the whole thrust of electric technology, including the computer.

We probably face a vastly altered musical culture of the future. We seem to be losing traditional concepts left and right, and there is a busy underground determined to smash any effort to hang onto any vestige of past traditions. In the face of this, many of the concert public choose to stay home or else they patronize the traditional concert hall. But my concern here is with the new composer himself. His predecessors enjoyed a tradition more readily communicated from generation to generation than any of the other arts. The teaching of music composition was

as thorough as that of mathematics. Now, I think you must agree, there is that avant-garde, only slightly underground, for whom this whole picture is quite changed. Without training, spending more time with electronic devices than with the piano, this composer must be his own teacher. He must make his own way and hopefully make his own traditions. I will argue that the magnitude of the transformation of new musical resources is such that we may perceive a quantum break with traditions more disrupting than anything that has happened in the arts so far.

I experience an especial empathy with these new composers, also a personal insight into their disposition, for my work with abstract film has been out in a limbo, too, where traditions simply are nonexistent. I am sure we both are dealing with some kind of mixed media we will share in common somewhere in the future.

It is now known that computer graphic systems are useful in the creation of a considerable diversity of abstract graphic form. It can be shown that the precision and detail of the graphics and the power of the computer to repeat thousands of images, each one with the most subtle incremental variation, makes for an instrument with superb visual motion generating capability.

This power of the computer to produce endless variations upon pattern, which stems from the basically mathematical foundation by which all images are formed, means that we have at hand an instrument for graphics that is analogous to the variational power of all musical instruments and the mathematical foundations of all musical form. Thus, computer graphic systems present an opportunity to realize an art of graphics in motion with potentials as unknown to us, perhaps, as was the far side of the moon.

The form of such art is unpredictable. While the forms and traditions of music and the dance may impinge in some way upon a computer art of motion graphics, this relationship in no way can be made explicit. The new art calls for a new artist and he cannot be called forth. He must literally find himself through the success of his own work with computer graphic systems.

Incidentally, it is not even conclusive that present-day hardware is adequate to support rapid evolution of new forms. While it is likely that musical composition with computers will progress coincidentally, it

may take a generation or two of technological refinement before we may see significant accomplishments. To date, practically no effort has been addressed to the design of hardware specifically for the arts of graphics or music.

But there is too much activity among contemporary artists with pure light and optical phenomena, and kinetics and light shows and multimedia experiments, to remain doubtful about the evolution of comprehensive new art forms with the computer as the classic instrument.

If anyone is repelled at the prospect of the machines taking over in the situation I have so joyfully tried to describe, notice, if you will, I am speaking to you from the humanities department, not from a basement in the science wing. I am speaking of new forms of art of human proportion on a human scale. Your general approval – your acceptance – is somehow necessary to me. I am interested in an art of design and color, and a new music. I know, for example, that thanks to new technologies, the possibilities for the experience of color in some formal context are greater than they have ever been in the past. That the computer is a new instrument in this business is no more insidious (I find it less frightful) than if it were the piano.

In fact, it has seemed to me the threat of the encroachment of technology, which the computer may symbolize to some, exists only to the extent that the humanities have failed to keep pace. There is much more to our problems than that, certainly. But far from repulsion, we cannot embrace rapidly enough the new culture that includes all electric technology within its integrity. Of course there should be, and there will be soon, I suppose, centers devoted to computer arts. And it will be a less apprehensive state of affairs when partisans for the arts and humanities express the same composure toward this computer world as is now commonplace in the scientific community.

John Whitney at Cal Tech 1968

These excerpts from a lecture at California Institute of Technology, March, 1968, are focused somewhat toward the scientific community, attempting to draw the scientist into a vigorous rapport with the art and technology issue. This appeal for scientists involved in art recalls the quotations from Sir Kenneth Clark and Dr. Jacob Bronowski in the A.S.I.D. talk reprinted above. – *W. M.*

As moments of history go, it is well-known that the end of a major war summons the end of private nightmares and the dawn of a long awaited new day. So it was for my brother and myself in the mid-forties, except that our released visions lurched ahead clumsily some twenty years into the future. The era we supposed was dawning, arrived in fact only now, more than two decades later.

I swear it is true that as I walked a chilly street in downtown Los Angeles winter, 1944, I was sickened with the conviction that a major crisis with smog was clearly at hand which would demand immediate attention from that day onward. With no less anachronistic delusions, but slightly more cheerily, I expected during the same winter that within a year or so television technology would burst upon an era of abstract design and typography, bringing with it unfamiliar delights of music for the eye to enjoy and a language of information that would mean the ascendency of a new way with words and ideas that are still not clearly foreseen nor even describable. Yet to participate in all this my brother and I were already embarked upon filmmaking careers with abstract films.

Back in those days, my brother and I had no sooner begun to yield to an excitement for this kind of filmmaking than we realized how deeply we were to become involved with technology. In an inconspicuous and not necessarily unique way, this art-technology relationship that we struggled with predates the proliferation of artists employing industrial

and scientific technology. Cooperation from industry, especially the motion picture industry, was very difficult to obtain.

As my own work progressed through the fifties, I came to a kind of intuition that a mechanical or electrical design instrument was the missing link in the realization of this abstract art of graphics in motion. I began to invent design machines. I explored the free swinging Lissajous pendulum as a pattern-making instrument. And I began to search through the war surplus junk yards like an archaeologist piecing together complex machines of some other world, since the dealers had dismantled most of the complicated World War II machinery simply because it retailed faster and more profitably in small pieces.

This way I discovered the diverse family of mechanical analogue computing devices used mostly as antiaircraft weapons fire control systems. I began to understand vaguely how these systems worked and I slowly learned how they could be converted into electro-optical graphic design machines. They were easily converted into machines for dealing with sine function geometry for example.

It was only with a kind of hindsight, a kind of delayed double take that I realized I was working with a machine that was really a mechanical model of the modern digital computer graphic systems. But once having achieved this understanding, my own contemporary perspective was to follow rather logically from that discovery.

So I could reason quite comfortably that just as the computer holds such promise in many scientific fields it must also represent the ultimate weapon – or less dramatically – the ultimate instrumentation for new dynamic graphic arts as well as music.

Yet the problem might have arisen how could anyone in my position be able to arrange to use the computer if he was not trained and his purposes were in no way connected with the scientific or technical fields normally using the computer systems around the country.

But this problem of qualification did not arise. It did not because slowly there is emerging out of the sometimes rather lurid flux of modern arts an art-science interplay. This art-science meeting ground is not exclusively due to the initiative of artists of course. The scientific community is ever more prepared to look across compartmentalized thresholds that once separated the human psyche and the human anat-

omy, for example, into isolated domains of art and science respectively. Furthermore, after C. P. Snow, the chasm between science and the humanities has been well accounted for in terms of communication or its absence.

The first generalized broadscale acceptance of ideas recognizing the relations of art, science and technology in art circles around the world seems to be occurring right now even though the Constructivist art movement has represented this viewpoint since the days of the Bauhaus and before. Perhaps now the cinema-television arts will affect an integration with their technology. With such integration should come a clarification of the true thrust and potential of the cinema medium for communicating message on a hundredfold different levels than has been known to date.

An unknown world of communication remains to be discovered within that area of visual experience bounded by color and pattern in motion and structured in time as in music. Typography, the unspoken word, can function in new ways within this realm of visual experience. So can the representational image, often in its broadest symbological, nonverbal, syntax. Of course, music and sound in general belong here.

Music, often called the one truly universal language and looked upon, in some special cases, as exemplary of the highest cultural achievement of Western civilization, stands to be superseded as a communicating force when new arts of totally intermeshed image and sound become a part of daily life. Quite naturally then, the technology of computer graphics demarks the beginning of a new era as surely as we are witness to the end of an old.

We may look forward to media of communication which are *in utero* today but which in the future may actually underpin the very structure of technological educational media and art if there is to be art.

The first point of consideration in support of this view should be an examination of the meaning of structure or organization as it is understood in relation to modern concepts of information and knowledge. Professor Frederick B. Thompson of the California Institute of Technology has stated in a recent talk:

"Experience underdetermines theory. Right there is room for those swift strokes of genius that sketch the underlying structure on which the distillations of our observations find harmony and

projections beyond our experience find credibility. Data are to the scientist like the colors on the palette of the painter. It is by the artistry of his theories that we are informed. It is the organization that is the information."

"The organization is the information," indeed. I wish to propose that so far as the educational process is concerned, so far as art is concerned, we have hardly begun to comprehend the possibilities for meaningful reordering of information by the graphic image in structured time. We just do not know what media lie ahead nor what the message capacity will be. But we may be well-disposed to explore energetically these possibilities of structure in art and information.

Interview with John Whitney 1970

This sensitive interview by *Film Comment*'s editor, Austin Lamont, asks some questions you may have wondered about while reading the main text, and it answers them with more interesting details about John Whitney's early career. – *W. M.*

To begin really far back, I had a couple of years at Pomona College, and at that time was interested in music and thought that I would possibly become a composer. Simultaneously, I was also intrigued in a technical way with film and with cameras. I had played with cameras when I was very young. After two years at Pomona, I went to Europe and spent a year in Paris. And at that time, two things happened. I was a neighbor of René Leibowitz, who's a conductor, known for his position with the French National Symphony Orchestra. But at that time he was best known as one of the outstanding pupils of Arnold Schoenberg; so he was writing and teaching Schoenberg music composition techniques. It was a very new thing, he was really of the radical avant-garde in Paris at that time, 1939, before the war. I had a very close association with him. I saw him two or three times a week over a period of several months. And so, though I had no formal training, I gained quite an extensive background in serial music composition that long ago. But also, the second thing that was happening was that I was there with an 8mm camera and intrigued with the idea of using it creatively. I had never heard of this kind of a film. I thought I had invented the concept of an abstract film. I began playing around with making abstract films. I thought of them as a kind of visual musical experience. It was only when I returned to California in the following years that I learned about Oskar Fischinger and the avant-garde filmmakers of the early twenties in Paris.

Q: You were in Paris and...

Whitney: ... Knew nothing about any of that. I met Man Ray in Pasadena after I came back, though he was in Paris when I was there. So really, when I came back, I began seriously to experiment with little abstract designs with an 8mm camera, and by about 1940, my brother and I were working together. Those are still, to my way of thinking, very interesting little films. They're hard to show; they're silent. I was working on file cards and animating with an airbrush, cutouts, stencils. The first film consisted of a simple circle and a rectangle. The two were juxtaposed over each other in a certain way. I cut a stencil that represented the circle, and another stencil that represented the rectangle, overlapping. And then I made a stencil of that clean circle, and a stencil of the rectangle. And then I made a stencil of the negative shape created by the circle and the rectangle and so on.

Q: Then you airbrushed cards through the stencils.

Whitney: Laying a card against two edges, and laying the stencil against the same edges, spraying a corner of each card lightly with the air brush, just start to fill in one little corner on one card. Then I take the stencil away and replace the card with a fresh one: and this next one will be filled in this much more, and the third more and more; and in ten steps, I fill out the shape. Then there was a possibility of using the negative, so I would put down the negative stencil of that shape and I would blow just a little bit around one corner and then airbrush all around, until it completely enveloped that shape. So I had the shape in a positive form and a negative form, and the motion generated by these cards was quite a lively motion with a front edge that would fade out characteristic of air brush. So, just from that simple technique, I had a whole library of all these different air brush sequences. They added up to about one hundred fifty to two hundred cards.

And at that point then, I conceived of the idea of using the optical printer, and having made these cards, I photographed the cards onto 8mm black-and-white film. I built an 8mm optical printer, so that I could rephotograph those sequences according to a carefully worked out script,

introducing color filters into the light source and photographing the sequences onto color film. And so I developed the technique that I am still using here with the optical printer now, with the computer-graphic material. [Indicates optical printer nearby.] Here's a light source, then a mirror goes here, and the filters rest on top of this condenser lens. Up above I have a lens tube extension and bellows arrangement, and the lens is normally at one-to-one; the field travels east and west and it rotates on its own dead center and another rotational point. It rotates down here, as well as at this level, so I can locate a rotational center that's off the center of the field.

Moreover, the camera goes up or down, so I can enlarge or reduce the field. Now the first 8mm optical printer had none of these complications. It was straight one-to-one, and I had no power to reframe the image. The film was built entirely within a very strict set of limitations. But completion of the 8mm films was one of the peculiarly rewarding experiences in making film, because despite the limitations, I had control of all the possible permutations of that original material, and it was amazing how many effects could be worked out, how many little variations could be made. They were quite interesting complex rhythmical actions all determined by the way these sequences were combined. The other point is that there's always more than one superimposure. I'd back the film up in the camera and then run through a second time with a second color, some other element, working in a different way. The final thing is that the filmstrips could be threaded into the projector in such a way that you could mirror them, turn them over, or you could invert them. So, you had four different positions for each of the ten shapes. And there were still some other variations.

It was truly gratifying, and it was stimulating enough so that we went on and made a 16mm optical printer. My brother and I felt very strongly that we wanted to be able to compose music as well as the picture. I invented a pendulum machine for making a variable-area sound track; and with that my brother and I together made the five abstract film exercises, through about 1944. Those are the films that got many showings. They won a first prize at the first experimental film competition in Belgium, and the Museum of Modern Art took prints, and Amos Vogel started distributing them through Cinema 16....

The *Five Abstract Film Exercises* takes me up into the late forties; I had a Guggenheim Fellowship for two years and during that time developed some spontaneous real-time animation techniques. I could manipulate paper cutouts to music. I was working with jazz – music that had no pretensions or none of the complexity and subtlety of structure of traditional Western music. I was finding ways of generating a visual motion by ways that avoided the tedium and the restrictions that you get by any cell animation or any conventional techniques. I was manipulating cutouts and working with fluids, very much as they are used in the light shows. I had an oil bath on a level tray with the light below. I put dye into the oil until it was deep red, and then used red-blind film in the camera. With my finger or with a stylus, I could draw on this thin bath of oil; and that would push the oil away and the light would shine through so I could draw linear sequences very freely; and by selecting the weight and thickness of the oil, I could control the rate at which the line would erase itself, so that it was constantly erasing with a constantly fresh surface to draw on. I was doing that and manipulating paper cutouts, and then doing a lot of direct etching on film as McLaren had done. I made, during that time, half a dozen little films to classic jazz such as Will Bradley.

Q: You mean, you put the jazz on, and as it was playing you would draw.

Whitney: I would do these things, yes, real time. I was building all of my own equipment all the time. I had a Selsyn interlock system. The soundtrack would have been previously recorded, and it could be run backward and forward in interlock with the camera. The only cue I had was what I could hear; so I'd rehearse two or three riffs of a piece, plan it more or less spontaneously right there and then shoot it, then back the film up and work on another section or over the same section, a superimposure over that, and then shoot it. I'd shoot a whole three-minute film in one afternoon's work. Those things were shown around a lot. They were shown in Belgium at the Universal and International Exhibition of Brussels in 1958.

Q: Did you run them through the optical printer?

Whitney: No, those were all generated in the camera. I was experimenting a lot with contact printing ideas; I would combine positives and negatives. I would do one sequence and then print it in one color and a different sequence with entirely different kinds of action and print it with a second color and possibly a third color. The film, *Celery Stalks At Midnight,* was made that way in two or three colors. And another film, Dizzy Gillespie *Hot House,* I did that way.

Q: Then did you go back to working more with an optical printer system?

Whitney: No. That work pointed to a kind of spontaneous performance – real-time performance. It pointed to something else, to give up film techniques entirely and to try video techniques. I made a proposal in the early fifties at UCLA to set up an arrangement with six or eight video cameras and six or eight performers using these various manipulation techniques, and the cameras were to be mixed electronically – then you'd perform a real-time graphic experience as an ensemble: and it seemed to me that it had great validity, and I still think very highly of that kind of a possibility. I'm surprised that the people working with the light shows haven't really ever done anything like this in that way. Their work is so totally unrehearsed and spontaneous. Even if they do rehearse – and some of them do – few of them have really thought of a kind of structuring of graphics. They're more concerned with a kind of storytelling, as far as I can see.

A commercial venture could never put up the money to pay a whole orchestra. But at a school, it could have been set up, and maybe it will be. A group might work together, and develop the same rehearsed dexterity and professional skill as an ensemble that you find in music. This goes on all the time with music groups. They all work together to develop great sensitivity, and spend a tremendous amount of time rehearsing and developing interactive responses.

Q: The proposal was turned down?

Whitney: Yes. The video communications department at UCLA, just as it is at any other university, is oriented toward either educational television

or training for the television profession, training directors and so on, and they stay close to the standards. They follow instead of lead.

Q: What did you do then?

Whitney: Well, by that time, the late fifties, I was becoming concerned with the concept that the whole media of motion pictures was not the media that I thought it was, that actually what the motion picture camera would see to record is the thing that's important. I began to give my attention to mechanical design machines. It coincided with a growing skill that I was developing with the technology of the surplus junk yard.

And so, by 1957 or 1958 I was on to these analog computing devices that were used as antiaircraft gun directors, and aware of the fact that I was able, for pennies, to buy mechanical equipment that's unbelievably costly, and involved fantastic skill in engineering design and production. And I began to see these things as containing within them, somehow, the possibilities for a very flexible design tool, which should be the thing of my interest, instead of trying to improve cameras or develop other camera techniques. And that led me into developing my animation machine. The film *Catalog* was made on it.

Q: It looked like a lot of oscilloscope images very carefully controlled and moving in a very precise fashion.

Whitney: It actually is doing mechanically what an oscilloscope would do; and that's when I began to realize that what I was doing mechanically could be done on the cathode ray tube computer terminal. In about 1966 I made a proposal to IBM, and I began operating under an IBM research grant. That's where I am now. But between 1958 and 1966, I used the mechanical-optical machine primarily to make a living. It became quite successful. I did a number of commercials and feature film titles, and titles for television shows, using that equipment.

Q: Did you make any of your own films with it?

Whitney: The Museum of Modern Art is distributing *Catalog* now, but I

never thought of it as a film. I didn't enter it in competitions and never thought of it as a work of art. It was what it was – a catalogue. I used it as a sample reel.

Q: How was the film Lapis *made?*

Whitney: Jim made that, my brother. He continued to make films, he was not so much hardware-minded as I was, and he worked patiently by himself. He lived over in the valley out in California. The fact that he lives in the valley and we live in the Pacific Palisade means we're in two different worlds practically. We kept in touch and had quite amiable contact with each other. And in fact, after I got this cam machine built, Jim finished a film titled *Yantra,* by the same technique that we had used from the very beginning. He much more carefully, much more patiently, made elaborate cards of hand-drawn dots – thousands of dots – and then subjected these to optical printing procedures where patterns of dots were piled upon patterns upon patterns, one level after another, then solarized all of those sequences, and printed them in different colors. When he finished *Yantra* it was shown around extensively. I think it was finished in the late fifties. Then I had my cam machine operating, and I helped him construct a similar machine for himself. He started working on *Lapis.* The year 1963, when I went to the Belgium experimental film competition, he finally reached that absolute end point. He was having such frustrations with his machine. It was getting at him so strongly that he finally decided that he was not going to go on and work with film at all. He became interested in ceramics. And so *Lapis* sat around in cans for two or three years. Jordan Belson persuaded him to put it together in its present form. He's not been making films since then.

Q: Did you do anything between the cam machine and the IBM computer?

Whitney: No, but during that time, actually, my sons and Jackie [his wife] were beginning to get involved in making films. And when I became a consultant for IBM, that left the cam machine free for them to work with. Each of them has done things with it. Jackie's getting more and more involved. My oldest son John has been making very signifi-

cant refinements of that machine this year, changing it over – adding another level that was beyond me, working with servo systems, the most sophisticated of electrical engineering technology. Servo systems are not like Selsun systems, they are motors that run according to computerized information that you give them. They'll run fast or slow and under absolute control. What's actually shaping up is the probability that that machine is going to become a functioning optical system under computer control. This we're expecting. We may very well finance this next year and, if we do, I'll have a system with almost the same potentials as the programming system that I have with the IBM equipment in my own machine.

Q: What else are you doing? As if that wasn't enough?

Whitney: Well, that's about where it is. The thing to emphasize beyond that is that I think this kind of film is starving for want of much more creative imagination in the area of formal esthetic creativity.

Q: The hardware is so dominant in the whole process.

Whitney: That's so. And there are periods all the way along when they screwed around with all kinds of machines and then finally they learned to fly, in all that time no real flying was taking place. But we are, I feel, approaching a time when we'll have something that flies and with that, the really important emphasis should fall completely away from the technology and the hardware and we'll be face to face with the real problems. I am quite gratified in these last two years because, in a way, that's exactly what I've done in my relationship with IBM; I have not had to worry about hardware there. I have a system here which I described to you, but it's an established system; I haven't had to be innovating or messing around with inventing new technical problems. Nor have I with the program that I've had. The program that I've had has had a few refinements made during the time I've used it, but essentially it's the same one that I started out with. And so, I've really had three years of the most rewarding creative study... and I think that's been enormously valuable: I think that I'm getting insights into struc-

tural solutions to learn how to make a graphic experience with some impact and done with some feeling and not just as a mechanism. I think, in that sense, *Permutations* is suggestive and points in that direction.

Q: I think you've been doing this in the films. You're very strongly taken and gripped by this thing you're looking at and you don't care how it is made when you watch it. You just want to watch it.

Whitney: Well, that's what I hope is the response.

Appendix

Animation Mechanisms 1971

This article provides the best introduction to some of the hardware/machinery John Whitney has been using to produce his films. *American Cinematographer,* Hollywood's professional journal, commissioned the article, which was a triumphant breakthrough for an independent filmmaker. – *W. M.*

The October, 1969 issue of American Cinematographer contained an article on filming the Star Gate sequences for *2001: A Space Odyssey.* Reference was made to my animation mechanisms and I have been invited to describe these.

As early as 1957 I had begun to construct mechanical drawing machines, reasoning simply that since the motion picture phenomenon is a precise incremental stepping process, a drawing tool capable of incremental variation would be useful. It is important to explain that I was not motivated to create representational images with these machines but, instead, wanted to create abstract pattern in motion. Since 1940, I had found myself devoted to the concept of an abstract visual art of motion structured in time, having for some years reflected over and over again upon the extraordinary power of music to evoke the most explicit emotions directly by its simple patterned configurations of tones in time and motion. The tendencies of much art of this century toward abstraction and kinetics served to reinforce these views during many moments of serious doubts of the validity of my own concepts.

My first machine, 1957, was immediately put to use in an unexpected way when Saul Bass included a few short sequences, drawn upon hundreds of animation cells with the machine's stylus, for the title to Alfred Hitchcock's film *Vertigo.* For one with such visions as mine centered in the fine arts, (an art so "fine," incidentally, as to be quite invisible), such

applications as titles to a not very significant movie were scant reward.

Also, I soon saw the absurdity of a drawing machine producing countless animation cells which had to be photographed in turn onto motion picture film. So my next machine replaced the drawing stylus with a light which optically exposed the image sequences directly onto motion picture film by the simple dynamic process of holding the camera shutter open while the light itself completed one excursion for each frame.

It soon became clear that there were plentiful absurdities in this procedure, since, in effect, I found I had labored long and hard only to produce hardly more than a mechanical equivalent of the cathode ray tube oscilloscope.

The mechanical motion which first moved the drawing pen over animation cells and, later, the light to and fro over the objective field of an ordinary animation stand assembly was merely a set of crank and lever arrangements similar to the ubiquitous child's circle pattern drawing toy or the more elaborate drawing or etching mill used in the bank note printing industry.

By this time, however, I became aware of two areas of possibility, the coincidence of which had considerable effect upon the following developments.

I began to comprehend how camera advance, art work, orbital and rotational motion, and illumination, could all be knit into a comprehensive automated functioning system. Simultaneously I acquired, (not exactly overnight) a highly specialized skill in adapting the almost worthless mechanical junk excreted from army depots across the country as the Army, Navy, Air Force and Marines unloaded material on the surplus market. Junk such as brand new thirty-thousand-dollar antiaircraft specialized analog ballistic problem-solver computers dating back to World War II.

My next machine employed hardware from war surplus: Selsyn motors to interlock camera functions with artwork motions; ball integrators to preset rate programming of some motions; and differential assemblies to control the incremental advance of the motions as each frame advanced.

Instead of a point source of light capable of drawing only lines, the

camera was fixed above a light field about twelve inches wide. Artwork consisting usually of film negatives of typography or rudimentary abstract patterns (clear images on an overall black field) could be orbited, rotated or moved in a great variety of compound sine function excursions within the twelve-inch light field.

The camera above was motorized to advance one frame automatically at the instant of the completion of one cycle of the artwork motion. Driven through a clutch-brake and continuously running motor, camera advance was made as rapid as practical to minimize that blind segment of the artwork cycle required for pulldown for the next frame to be exposed. Thus, throughout the major portion of the artwork excursions the camera shutter would be in open position.

In order to clarify the simple principles involved here we may take as an example of sequence from my film *Catalog*. A film negative having "1961" (clear type face on a black field) is mounted on the artwork holder. This artwork is attached so that "1961" is located at dead center in the camera field when viewed through the rack-over viewfinder of the 35mm Mitchell camera (crank and lever mechanisms had been replaced by a more elaborate variable amplitude compound cam assembly by this time).

The art, "1961," so positioned in center field, can be articulated by the cam system which, for the moment, is set at "0" amplitude. The light field below the artwork is turned on, then the entire system is turned on. Artwork "1961" sits there throughout several complete "0" amplitude cycles while the camera advances at the completion of each cycle, exposing on each frame the image "1961," immobile at dead center field. Now the amplitude controls, through differential gears, begin a minute orbiting which moves the art on an orbit with an increasing radius whose center is still camera field center. The simple image, "1961" now begins to be transformed into a progressively less readable pattern. The pattern that is produced, moving as it does, smoothly, and expanding outwardly, will continue to hold visual interest if only as a simple attractive abstract pattern. (See illustration, Figure A.)

If, instead of a continuously operating filament-type light source, a strobe light is used, the continuous pattern on the film can be broken into individual distinct overlaying images such as those illustrated. (Figure B)

I have selected both of these simple actions to suggest some of the possibilities of which the machine is capable. My film *Catalog* (see cover illustration) is a more diverse demonstration of the versatility of the machine. This film, used as a sample reel, was to be very productive of commercial assignments in the following years. The titles to the Chrysler, Bob Hope Television Show and portions of *To the Moon and Beyond* of the New York World's Fair, Alcoa commercials and titles to the Dinah Shore Show were typical. Of all the productions of this period, however, the one film which will probably endure was produced with my second version of this machine and made by my brother James. The film I refer to is titled *Lapis*. It has received many awards and continues to be a very popular film.

The following is a description of the effects seen throughout *Lapis*. Most of the patterns are center-oriented, constantly moving dots of color which continuously reform into new concentric arrays. They were achieved by a strobed rotary action of the artwork which combined an orbit, whose diameter was constantly changing, with drifting rotation. The artwork consisted usually of nothing more than a simple random dot pattern which was hand drawn.

My brother and I were much intrigued by the results achieved by these simple random dot inputs. It was astonishing to discover the variety of orderly patterns generated by as random a source as these dot patterns. The original artwork contains no hint of the patterns that were produced. (Figure C)

The above descriptions, however, still represent but the simplest of countless transformations that can be achieved with essentially the same mechanical system. For example, the shape of the orbital motion can be varied into back-and-forth motion on any angular axis with the X and Y controls of the compound cam assembly. A straight back-and-forth motion along a line at right angles to a line of type for example produces an effect such as that illustrated. (Figure D)

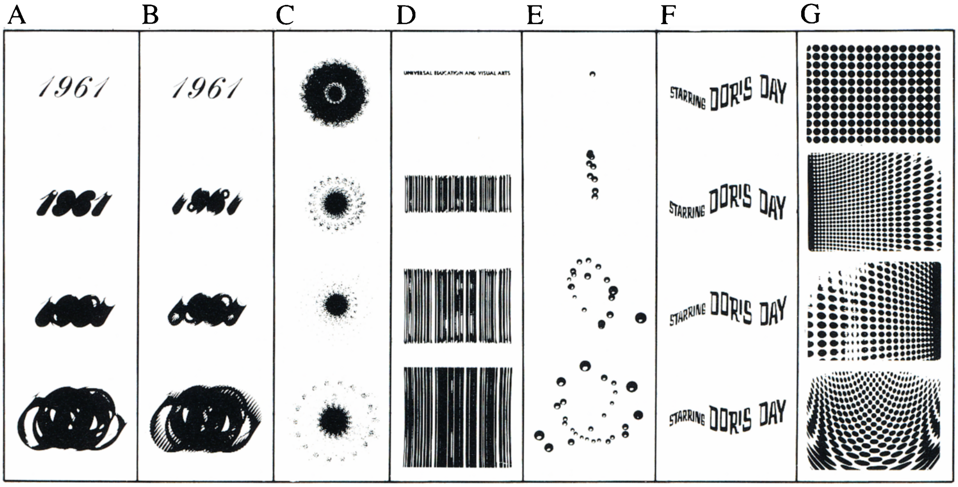
Countless further variations can be produced by altering cycle phasing relative to camera advance or exposing only some fraction of each cycle or by changing the timing of the illumination, its frequency and/or its on-and-off duration.

These possibilities are greatly expanded by inclusion in this fully

integrated system of a servo-motorized zoom lens. The zoom cycle is phased and operated through all or part of its full magnification range in cycles that coincide with the various excursion cycles of the artwork. The illustration (Figure E) is from a commercial for a milk product made in 1964 and was generated from artwork consisting of a careful hand-rendering of a single droplet of milk. In this case the orbit of the artwork began with the zoom lens at about midpoint of its magnification range. Then the zoom was operated through progressively greater magnification amplitudes per cycles as the elliptical orbits of the artwork were modified. The drawing was strobed nine times per cycle, producing a ring of nine orbiting spheres.

Finally, since my earliest casual interest with motion picture photography had been in a college astronomy department, I was familiar with various applications of optical slit-scanning connected with solar spectroscopy. It was, therefore, logical to apply these principles to my motion picture system. The titles for MGM's *Glass Bottom Boat,* and many other commercial assignments, were done with a slit attached to one element of the compound cam assembly. The typography was attached to the other cam. The slit was set to move one full excursion across the full width of the type, while the type moved north and south one or more times per half-cycle of the slit. The return phase of the slit-scan cycle

A B C D E F G



was accomplished while the camera shutter remained advanced, one half cycle, in closed position. Since there was a preset differential drift of the north and south movement of the typography the lettering on the screen appeared to undulate smoothly as if in water. (Figure F)

The combination of this slit-scan technique with zoom produces very pronounced spatial motion in depth. This is specifically the slit-scan effect used to produce the Star Gate sequence of *Space Odyssey.* My son's film, *By Jina Flores* was produced by this slit-scan zoom combination. The artwork consisted merely of a standard Benday process overall dot pattern with a slit-scan and zoom cycle in differentially drifting interlock. (Figure G)

This existing machine is grossly overdesigned. As a prototype, many experimental subassemblies have been installed and removed or permanently established over the recent years. In fact, like some machine tools, each new film assignment involves some hardware assembly or knockdown. The machine practically fills the room into which it was built. The machine was featured on a CBS 21st Century Television segment in 1968. Two overhead wood beams, 4″x 12″, span the room and carry the camera on a transverse dolly hanger assembly whose movement is free and independent of the artwork manipulating mechanism and illumination table below. This camera hanger assembly permits 360° continuous rotation of the camera, and back-and-forth straight-line travel over about twenty-four inches. The assembly connects all the camera's electrical leads; selsyn, film advance, zoom functions and phase shift through slip ring contacts to permit the continuous around-and-around camera rotation. These camera motions, of course, can be phased and synchronized precisely with the artwork motions below.

The artwork table below can be rotated 360° as a total unit, but cannot be operated continuously around because of its electrical connections. Since some of the cam functions have been covered already I will skip any further description except to say that at present the machine possesses four complete cam assemblies, any one of which can be set up to manipulate artwork or scanning slits or color filter patterns, etc. These units can be compounded in various ways to produce sum and difference effects.

It is somewhat idle information to count components but as an index

of the complexity to which this kind of design system can be extended, the following statistics are suggestive:

17 Bodine Motors
8 Selsyns
9 differential gear units
5 Ball integrators

This present machine is now serving to test out a vastly simplified and rationalized system operated by servo drives and controls which, with a designed interface, will permit direct digital computer control. The new machine will be marketed under a patent granted in 1963 and others in development.

In conclusion, may I be permitted a comment from a very specialized point of view:

My optimisms are more secure today than in 1940 regarding the arrival of altogether new forms of art for television and the newer home library cassette systems. I foresee new forms of abstract design and typography, which will bring unfamiliar delights of music for the eye to enjoy and a language of information that would mean the ascendancy of a new way with words, images and ideas.

Any casual viewer of television throughout the year 1970 may have noted that graphics, especially typography, have found a new dynamics that is quite happily suited to the television medium. For example, in 1970, three major networks sponsored promotional interludes that anyone with an eye for design could respond to with unreserved pleasure. Yet, television in the United States, which is sometimes a thing of national pride, is far too frequently a matter of national disgrace. Aside from bad taste, bad design, establishmentarianism and commercial imprudence, the problems of television still have much to do with a medium that seeks to find its own "right way to fly." Traditions, especially from the theatre, are still a deadweight against flying new video ideas. My work has always been with new kinds of "flying machines."

Computer Art for the Video Picture Wall 1971

In this address delivered in 1971 to the International Federation of Information Processing Societies, at L'jubliana, Yugoslavia (and published that year in *Art International*), John Whitney links his philosophical discussions of music theory to specific examples taken from his computer film *Permutations* and *Matrix* films. Further notes on *Matrix* are appended. – *W.M.*

It has already been suggested by Ivan Sutherland that computer graphic visual displays, like the telescope and microscope beforehand, have begun to open to our vision a heretofore invisible world. We can say that the computer has the power to bring about visual enlightenment with regard to much in the world that was formerly abstruse mathematical data. For example, periodic phenomena of nature that could be understood in mathematical terms only, have often failed to have meaning outside the society of mathematicians and scientists in general till the present when computer displays are beginning to present new real-time visualizations of these phenomena.

One domain of periodic phenomena, however, has had its impact upon our sense of hearing. This domain has been a matter of deep interest and feeling and even considerable understanding to artists. The immediacy of impact upon the audio sense is unequivocal here. The artists to whom I refer are the musicians and composers of the world's diverse musical cultures. And their periodic domain is of course the audio spectrum of music with its tones and rhythms, its harmonic interrelationships.

It is interesting to speculate how early in prehistory it was that man stumbled onto a system of ordering the audio spectrum. Here was a continuum, a chaos, of infinite frequencies existing between the lowest tone – roughly 18 or 20 cycles per second – to the highest, say 18,000 Hz. Yet, long before Pythagoras, the simple intervals of the octave, the

fifth and fourth were extracted and used constructively by musicians and chanters. Addison in his journal *The Spectator,* in the year 1711, assigns to Pythagoras his traditional claim to fame, an anachronism of music history which was a common error of the 17th and 18th centuries: Pythagoras, wrote Addison, "... reduced what was before only noise, to one of the most delightful of all sciences, by marrying it to mathematics; and by that means caused it to be one of the most abstract and demonstrative of sciences."*

We know very little about the music of earlier civilizations (music was so perishable) but the music of Western European culture since the 14th century has been held in great esteem, often honored as the very highest intellectual achievement of Western civilization. And one further point is that, at least until the beginnings of our present era, music and science progressed hand in hand, with considerable interest shared by scientists and artists interchangeably over the mystery of the mathematical verities underlying the structure of music and their relation in turn to the rhythms of the cosmos.

In a way all of this has been obscured by modern preoccupations, and yet the relation between mathematics and music has not been discredited. Although Jean-Philippe Rameau and others did not succeed in their efforts to discover a comprehensive mathematical foundation for music, we can state with certainty that there is an implicit and very complex order of periodic structures behind most of the musical art of all times.

Let us say it is one of the fortuitous happenings of nature that a vibrating string of fixed length and tension sounds a characteristic pitch of tone consistently. But to embellish this tone to aesthetic perfection, violin makers devoted several centuries of exacting sound box experiment. They were engaged, without ever calling it that, in research upon a harrowingly complex periodic waveform study designed to satisfy a particular human sensitivity.

Today the computer offers a means to deal analytically with periodic phenomena of such subtle complexity, suggesting that we may come to

**Philosophies of Music History*, A Study of General Histories of Music 1600–1960, by Warren Dwight Allen. Dover Publications, Inc. New York, 1962.

an understanding of some of the profusion of quandaries that permeate musical analysis. John R. Pierce, discussing the computer's powers to synthesize music, confirms the complexity of these problems:

> We are faced with an intriguing challenge. In principle, the computer **can** become the universal musical instrument. All that stands between us and all that was previously unattainable is an adequate grasp, scientific and intuitional, of the relevant knowledge of psychoacoustics. Both by experimentation, and by careful measurement and analysis of musical sounds, we must find among the bewildering complexity of the world of sound what factors, what parameters are important, and in what degree, in achieving the effects at which we aim: all the variations of sound that we hear from a skilled instrumentalist, all the characteristic sounds of instruments, the rich massed sound of the orchestra, and everything that can possibly lie beyond these familiar elements of music.*

But more to the point of this presentation I wish to stress new visual powers of the computer. Computer graphic displays offer an entirely unique method of dealing with **visual** periodic phenomena. The computer can manipulate visual patterns in a way that closely corresponds with the manner in which musical instrumentation has dealt with the audio spectrum since the first strings, skins, metal and reeds were used to make music.

A modern study with computer graphics has begun which is somewhat similar to that Western European period in the development of musical art and instrumentation. In saying this I am confronted with an instantaneous assumption by most people that I am comparing the audio spectrum to the spectrum of light with its colors. No such thing is the case. The similarity of tones to colors has caught the imagination of many composers and painters and philosophers since Leonardo. Yet today we may look upon this viewpoint as being rather too simplistic. Here is a typical expression of this viewpoint in a quotation from George Santayana:

> There are certain effects of colour which give all men pleasure, and others which jar, almost like a musical discord. A more general development of this sensibility would make possible a new abstract art, an art that should deal with colours as music does with sound.○

To come nearer to the truth of this matter one may turn to John Dewey

Cybernetic Serendipity, The Computer and the Arts, A Studio International Special Issue edited by Jasia Reichardt. Studio International, London, July, 1968.
○*The Sense of Beauty*, by George Santayana. Published by Modern Library and Collier-MacMillan, 1896.

for another prediction of a future art that is astonishingly like Santayana's in some ways but also significantly different:

> Today rhythms which physical science celebrates are obvious only to thought, not to perception in immediate experience. They are presented in symbols which signify nothing in sense-perception. They make natural rhythms manifest only to those who have undergone long and severe discipline. Yet a common interest in rhythm is still the tie which holds science and art in kinship. *Because of this kinship, it is possible that there may come a day in which subject matter that now exists only for laborious reflection . . . will become the substance of . . . (art) . . . and thereby be the matter of enjoyed perception.**

This idea, set down well before computers were born is exactly the point I wish to make. Let me repeat, the computer graphic display can make perceptible to the sense that which was heretofore invisible except to the educated discerning mind. Certain phenomena, especially periodic aspects of the world of mathematics, that which has so intrigued the specialist as to evoke in some trained observers a sense of wonder as with music itself and often thought of as akin to music can now be made accessible to direct visual experience.

R. Buckminster Fuller has talked about this matter of direct experience in another way. He places emphasis upon the function of the artist to humanize and communicate a modern world vision. He reminds us that this century's science and technology have discovered and put to use practically the entire electromagnetic spectrum, which is still, to the senses, invisible and quite incomprehensible to the individuals whose lives are transformed daily by new technology. This makes for a large part of the chasms of misunderstandings, he says, that characterize the latter part of the 20th century. Fuller rightfully comprehends the possibilities for new arts in these freshly discovered domains, and the cultural imperatives of a restoration of kinship between science and art.

Now neither Buckminster Fuller nor John Dewey nor Santayana has the last word on the overlapping domains of art and science. But their words tell you much by way of background to the field that I have been involved with throughout the last five years. I have been using the computer as if it were a new kind of piano. Using the computer to generate periodic visual action, with a mind to reveal harmonic, juxtaposed against enharmonic, phenomena. To create tensions and resolutions and

**Art as Experience*, by John Dewey. Minton, Balch and Company, New York, 1934.

to form rhythmic structures out of ongoing repetitive and serial patterns. To create ordered variation of changes. To create harmonies in motion that the eye might perceive and enjoy.

I do not pretend to have advanced far beyond elementary exercises with the few films I have to show. In fact, as I listen to some of the earliest known ensemble compositions of anonymous 13th century composers of Europe, I envy their skill and sophistication with their young art. Yet it is historic fact that the process, underway that long ago, somehow foretold the achievements of Bach and Mozart. Was it not a kind of collective learning process? Learning to manipulate and construct such an enormous variety of periodic phenomena of pitch, rhythm, tonal relationships and dynamics. At least we do know that learning and invention progressed hand in hand with the refinement of a great variety of instrumentation capable of satisfying the musical discoveries of composers by providing hardware with which to realize their compositional software.

The marvel of the modern computer need not de-emphasize the probability that even smaller and more versatile graphic systems lie ahead. Nor the probability that future generations of artists will know better how to use these systems.

I have tried thus far to present a different, and I hope unexpected, introduction to my work in order to stress that it is not a film art like any of the forms of film art that are established and well-known today. I could say that what I am doing is more akin to music than to film art, but that too evokes preconceptions that I wish to avoid. All that my work has in common with music is, let us say, this patterning of various periodic phenomena in time.

Further remarks on analog and digital computer graphic systems

Computer graphic instruments are interesting for their possibilities for generating motion. In fact, there exists a vast unexplored world of movement and rhythm in abstract space which is now realizable thanks to this type of hardware. When we examine these images in motion in their spatial environment we find they can hardly be likened to any previously known visual experience. This space is unreal space that exists only by virtue of the motion of the abstract forms that move in it. Forms can interpenetrate one another. There are none of the limits of mass,

inertia and gravity such as real bodies in motion encounter. Acceleration and velocity limitations are the same as with light itself. Color can be varied as a free continuum of the visible spectrum.

One clue which has the smell of basic principle to it is a promising outcome of my research study. This clue has to do with periodic visual structures. By way of comparison, music is unequivocally periodic phenomena. Music is a continuum of periodic construction in time. I share a familiar ground with the composer who deals with time as a major component of his art by composing with periodic units.

Now I have a clue, a hint as to how visual elements can be set in motion in their own time and space. This clue indicates one thing: to deal with time as a major component of visual art, we must think quite differently about graphic form. To construct periodic elements with visual raw material, an entirely new concept of graphics must be formulated which places far greater emphasis upon time and motion than has ever before been assumed.

So far as I know, few have considered graphic art in periodic terms. Yet all abstract art from Piet Mondrian to Jackson Pollock and Frank Stella might be examined for rhythmic components. Rhythm and dynamic forces exist in static potential; or in a state of frozen equilibrium, as Mondrian proposed.

We have a highly developed art of animation already a few generations old. But here also, no one that I know has ever proposed a theory of periodic principles, except on the elementary level that the single frame equals one twenty-fourth part of a second. The animation arts have not truly invaded the domain of abstract art as have painting and sculpture.

With the computer as an animation tool, however, its mathematical determinants have led directly into a new world of integer ratios and algebraic functions – harmonic phenomena which express themselves graphically.

First of all, since the computer positions and shapes any graphic object by x-y coordinates, it becomes the most natural way to position and move objects by way of some dynamic numerical functions of x and y. Immediately harmonic functions come to mind with regard to moving objects relative to each other. Thinking of graphic form, since it all must

be expressed in x-y or polar coordinates anyway, impels one toward number functions.

It is singularly ironic, to say the least, that most artist experimenters with computer graphics thus far have sought ways to circumvent the imposing fact that all their graphic conceptions must be translated into number functions. After resisting this rather tedious reality for some time, myself, I have come to welcome the mathematical basis of computer graphics because of the structural advantages I have discovered thereby. I have come to accept the numerical problems which are natural procedure with my computerized tool. Now I find that this very acceptance has opened the door to a new world of visual design in motion whose true essence is digital periodicity. But for some details that are not important, this is much the same world that the composer has known for at least a thousand years: composing audio design periodicity.

Remarks referring to *Permutations,* an 8-minute film made with the IBM 2250 Graphic Display Terminal

Now to illustrate, in some detail, what I might call visual harmonics. These 281 points are moving about the screen according to a set of instructions in a graphics program which were input to the computer. Incidentally, it would be difficult to find a better demonstration of the powers of the computer as an animation tool than this film sequence. Imagine having to animate by hand 281 points, all moving in precise orbits at independent rates and directions. The program instructions say, in effect: Starting at the center of the screen, step to the right a computed distance and move in an arc around to the left so many computed angular degrees and place one point. From there, compute a new radius distance outward and a new theta arc around and place another point. Now repeat this procedure again and again for a total of 281 points. This takes about a second or two computation time on the computer to produce only one frame of this motion picture. Each frame is slightly different because some of the parameters of the instruction equation are changing with each new computed picture. As you watch the picture on the screen here, 24 new pictures a second are displayed and you can see changes taking place sometimes very rapidly and sometimes quite slowly. This rate is determined by the size of the incremental steps, or the parametric

changes, as they are written into the basic equation. Now you will notice that the points seem to be scattered around in a circular area randomly at one moment. But at certain moments they all seem to fall in line to make up some simple rose curve, symmetrical figure; sometimes it is a three-lobed figure, or ten- or four- or two-lobed figure. These action sequences proceeding from order to disorder and back to ordered patterning, suggest a parallel to harmonic phenomena of the musical scale. In an aesthetic sense, they have the same effect; the tensional effects of consonance and dissonance. The scattered points fall into some ordered symmetrical figure when all the numerical values of the equation reach some integer or whole number set of ratios. The effect is to subtly generate and resolve tension – which is similar to the primary emotional power of music composition.

A Word About *Matrix*

Matrix is a short film consisting of horizontal and vertical lines, squares and cubes. All motion is along a closed invisible pathway (the matrix) which is a classical Lissajous figure positioned symmetrically within the motion picture field. The motion of the entire film is simply a sequence of events of clustering and dispersal of the lines, squares and cubes.

The sonata segments by Padre Antonio Soler were selected to accompany this film after the film was nearly in final form. Very little stretching or shortening of picture or sound was required.

Matrix was made at the California Institute of Technology as one part of the arts program initiated by the division of Humanities and Social Sciences with joint IBM sponsorship. The computer program was created by Dr. Frederick B. Thompson, Professor of Applied Sciences and Philosophy at Cal Tech. Called REL (Rapidly Extensible Language) system, this program permits construction of elaborate graphic images with highly controllable time development through the recursive aspects of its formulation. An advantage of this program is its interactive convenience. Design ideas can be formulated, input into the computer at a typewriter keyboard and then displayed by a selectable sampling of the action, all in rather rapid order.

Cranbrook Essay 1973

This important address delivered to the Computer Arts Society of America at Cranbrook Art Academy, May, 1973, elaborates the analogy between classical music and various visual phenomena, natural and cinematic. Here Whitney justifies his rejection of multi-plane simulation of everyday perception of motion from a fixed-perspective context. He also affirms that the intricacies of musical dynamics – the legendary defrosted architecture of Baroque music, for example – demand a wholly new moving visual counterpart so complex that only the new technology will be able to manipulate it. – *W. M.*

In a proposal a few years ago, I tried to present a visualization of some graphic possibilities that might be realized through careful research on computer graphic instruments. I tried to evoke an image I had myself seen many years before. The image was difficult to put into words. My capacities were inadequate to describe the extreme subtleties of a quite beautiful dynamic phenomenon of nature. I wanted to describe the turbulent activity of minute water particles that anyone can see in the space of about a cubic foot of densely foggy and quiet nighttime air – assuming exactly the right lighting conditions. Since these water particles are much smaller than the average raindrop and are charged electrostatically in such a way that they do not collide, they flow in casual turbulence moving freely and smoothly in all directions – upward as often as down and to left and right. These droplets behave as would a school of minnows or bees.

Yet my metaphors profane the elegance and the phenomenal beauty of the motion I was trying to picture, since bees and fish must propel themselves. They maneuver about rather awkwardly, whereas these microspheres of water are almost effortlessly pushed and pulled in three-space by a fantastic complex of interactive forces of unfathomable precision and curvilinear hyperdynamism.

I wanted to say in my paper that this image of motion was the one experience I knew firsthand with which I could honestly compare my feelings about many works of polyphony performed, for example, by a string quartet. Leaving out much else that connotes the power of music, at least the spatial interweaving of clean, delineated pattern was there along with forces of orderly interrelationship. Even if you could not possibly interpret the laws that govern this cloud of simultaneous trajectories, the strongest part of that utterly fascinating experience was its sophisticated conformity to rule. This fits my ideal of what music should be like. And in fact dozens of composers over several centuries in Europe have repeatedly confirmed that ideal.

I was always delighted with that parallel to music. Since here was a visual motion – of all things – which most vividly evoked the very qualities one enjoys through hearing music. More or less, that simple vision has sustained my career for almost thirty years. It has given me many special insights into film form. It sent me off constructing some rather unorthodox machines that supplement and systematize the motion picture photography of abstract motion. And in due time directed me straight to computer graphic instrumentation armed with convictions few people comprehend or share. On the other hand, I have not shared the confusion of many artists who may sense that there must be some great potential in computer technology, but who falter with their own definitions of purpose and creativity.

Having completed several computer graphic films, I find it is not difficult to attempt to sketch some first principles which might help to define a new visual art. Composers began early on – centuries ago – to attempt their own enunciation of musical principles. Otherwise our best composers would not have had the benefit of needed teachers. Most rules that composers learned in childhood or youth consisted of sets of prohibitions. Pope Gregory, in the 6th century I believe, established codices so rich in prohibitions and so strict in orthodoxy (not to demean the music) that excommunication awaited the nonconformist. Rules that state what **should** be done usually lie hidden in the musicians' own creative talents, and so only prohibitions surface where they can be apprehended and written down. Excommunication is not a bad punishment so far as I can see. I would recommend something like that for anyone

under my tutelage (if I were a teacher) who commits, for example, my pet prohibition. A rule that is akin to the largest family of musical rules governing parallelism in voice-structuring:

It is strictly forbidden to have anything to do with two or more points having fixed spatial interrelations.

In one overriding sweep, this rule forbids practically the universal convention of ordinary cell animation, the "pan" of backgrounds. Disney perfected the "multiplane pan" as a device for refining the illusion of realism and in so doing strengthened the static fixed interrelation of his hand-drawn pictures of the "real" world where foreground moves faster than middle ground, which in turn moves faster than background. All this is anathema in a conceptual space-time fluid universe where dynamic interrelations are the only constant; a nonordinary universe without gravity, scale or particularity, in contradistinction to the real world of observable Aristotelian fixity. Such a universe, my imagination could see in those illuminated mists.

The same sweep of my prohibition engulfs the favorite kitbag of a breed of cineastes whose zooms, pans and trucks, preferably handheld, have persuaded proponents of the Brakhage School that somehow camera movement and montage allows their camera to look cinematically into abstraction, beyond the real world in which they and their camera are fixed quite solidly despite their own frenetic activity. This cinematic unorthodoxy, (it has become a video technique as well) in their minds, instantly transforms an instrument, otherwise known for its recording and documentation functions, into an instrument for "poetry."* Perhaps it may, but is does not open the camera eye to the universe of fluid dynamics about which I am at pains to define in this essay.

In fact the camera eye, sensitive as it is, must be directed elsewhere than the "real world," if indeed it is to be called upon to record a fluid universe such as my turbulent water particles on a misty night. Were it possible to intervene in that complex system of nature and direct those billions of water droplets along their smooth noncolliding, perfectly curvilinear trajectories, then one might point his camera at them. One might command, say, four thousand droplets out of the approximate forty

*Annette Michelson, "Camera Lucida, Camera Obscura," *Artforum*, v. 9, #5 (Jan. 1973), pp. 30–37.

thousand in one cubic foot of fog. Command, upon a given signal from the cameraman, that these particles form into a perfect circle six inches in diameter. That happening would be a spectacle indeed.

Short of calling down from the heavens a miracle, there is no other way to produce a pure geometrical wonder such as a six-inch space floating ringlet, just happening on cue. If there were a way, it would be an event several magnitudes superior to the Hollywood or Russian spectacular. It would require a cast not of thousands but forty thousand, all participants cooperating in an enterprise bound to put DeMille down a notch.

And how dare I call a mere ringlet, a natural crown of jewels, called forth on cue, superior spectacle and greater than dramatized epics say, exodus of the Jews or the defeat of the Boyards? I derive this conceit from the argument of Socrates who had noble things to say about the nobility of geometry as the truest, and consequently the most beautiful. "They have that purity which makes for truth. They are philosophical."* Also I derive this from Mondrian's dynamic concepts, being a state of equilibrium: being, not dramatizing the spiritual and universal.○

Short of seeking in heaven this sort of thing, a way to do it by machine has been found very recently. A computer can deal with the coordinate positions of units in the hundreds of thousands. A computer which can cope with the tax data of a nation surely can cope with the coordinates of a mere cubic foot of free-floating droplets. It can, but it barely can. In fact, it can be done only by illusion and fakery such as the backstage of theatre. The numbers must be trimmed twentyfold or so. And the rules governing that free motion of particles in space must be synthesized, because this particular phenomena of nature happens to be one of the most obscure and quite unsolved problems of modern fluid mechanics.

Nevertheless the manipulation of particles in space has become the very foundation of my theoretical, philosophical and practical approach to computer art. Particles take on classifications as fields, conglomerates, clusters and transformational entities. Dynamically they generate and

*Plato, *Philebus*, 51 c.
○Piet Mondrian, *Plastic Art and Pure Plastic Art*, New York, 1945.

release tension by periodic, harmonic structuring, akin to music; they generate, transform and dissolve matter according to Hoyle (the astronomer).* The transformational attribute is in accord with much more than Hoyle, since the arrangement of many points by either density or intensity constitutes the basis for both the television-scan and the photo-printing processes. If an array of points can be caused to arrange themselves into the aforementioned magical, geometrically beauteous ringlet, they can at another time, and with some more sophisticated controls, be caused to transform and group themselves into any image a camera can photograph. Thus, if we gain mastery over the manipulation of a plurality of points it follows that we may rule the universe of visual display, that is to say, a universe which then becomes an ethereal continuum from pure geometry to pure representation of nature. Such is the power usually possessed by rulers of universes. That is not likely ever to be my power; but the history to date of slow progress in that direction is as follows.

My brother made *Yantra* in the fifties. This film was the fruition of at least fifteen years of work, during which we both had made films by a succession of principles, each one momentarily considered by hypothesis to be the basic unit, the least common denominator, the atom, or the simple building block for an art of abstract film. Jim had found in Fred Hoyle's hydrogen dynamic theories about the formation and transformation of matter in the universe, a poetic metaphor in harmony with Vedantic Cosmologies° and, happily, applicable to our film researches. He started drawing dots by the tens of thousands.

I, sharing his conviction, started looking for machinery, as is my personal disposition, to do so by a "better" method. The better method that resulted was an elaborate piece of machinery used by Jim to make *Lapis* which was a further exploration of dot-generated pattern that won prizes in the early sixties and continues to be a very popular film – by the standards of this kind of personal film – and a durable work of art.

There were many reasons to support our faith that we had conceptualized a root principle. However, anticipation that computer graphic

*Fred Hoyle, *Frontiers of Astronomy*, New York, 1955.
°Heinrich Zimmer, *Myths and Symbols of Indian Art and Civilization*, New York, 1963.

systems should one day dovetail with this principle exactly was not part of our reasoning; nor could it have been. But the idea of a point which, treated dynamically, produces a line which in turn produces a surface which generates a solid is an idea to be found in Paul Klee's *A Pedagogical Sketch Book.* It does truly anticipate computer graphic displays of the present-day vector scan principle to the extent that a dynamic point of light on the cathode screen is used to draw lines while close-packed lines generate surface.*

Our search throughout the years since 1940 may be characterized as a quest to revolutionize the visual artist's concepts of dynamism. If art in this century reveals a trend toward the evocation of the **image** of dynamism as exemplified by such movements as the Futurists, then we searched for a genuine art of movement. We were impressed by the number and frequency of traps and pitfalls by which, due to conventional thinking and graphic tradition, one's best dynamic aspirations fell short, frozen and static in terms of film dynamics. The tradition of fluid dynamic time, which is second nature to the music composer, finds almost a mirrored reverse polarity within the tradition of the visual artist. Time and space, the talisman of this century for both the arts and the sciences, have actually received less than lip service from the plastic artist. Film art, the child of this century, we came to believe, and we still do, conceptualizes time and space with childlike awkwardness if at all.

As a revelation, one need only sit at the piano and pick through any lento movement from a Mozart keyboard work, taking note of the timing markings and their effect, in order to realize the staggering grasp of temporal manipulation involved in musical composition. This disclosure, compared directly to cinema, induces one instantly to reflect that we have not even begun to understand metrical or rhythmic organizations of time in cinematic terms.

Critics of conventional cinema often praise film editing, etc. by applying musical superlatives. These critics I suggest might go back to the keyboard and ask themselves once again: is it really so? An argument can develop to the effect that modern musical conventions have almost abandoned metrical structure, to which the immediate response is that

*Ivan E. Sutherland, "Computer Displays," *Scientific American*, v. 222, #12 (June, 1970), pp. 56–60.

music of this century is hyperreactive to its own enormously successful past tradition. And, besides, popular music is still rigidly conventional and metrical. Then comes the clincher: is not cinema presumed to be a popular art? Conventional cinema is hardly the best proving ground for a musical avant-garde.

In more ways than one, the plastic artists, as well as their brothers in the musical avant-garde, conduct a rearguard struggle against their own traditions (sometimes even last year's tradition) with more vigor than they assault the "avant" itself; which points up the confusions surrounding the whole concept of the tradition of the new.* For myself, strangely, I have felt a certain placid aloofness to the issue of avant-gardism, being engaged in an effort to establish some tradition where none has ever existed before. My brother and I were told at an impressionable age by no less an authority, in our minds, than Tony Smith, that we were more or less "over-the-hill" into the culture of the 21st century (ironically for us as far as recognition in our time was concerned). We needn't concern ourselves manning cultural barricades, he advised, and we listened. Much as I admire Schoenberg's gigantic transformation of the prevailing concepts of metrical structure, I felt not the slightest need to follow in his footsteps, as most composers have since. Instead I consider it quite the most urgent challenge of my film art to clarify the myriad difficulties that surround rhythmical structuring of visual patterns of motion.

Any sensitive analysis of music shows that it is patterned motion that evokes emotion which is the content of music. Form and content happen to be two terms. What they denote in music is merely one thing, just as time and motion are attributes of one event.

So it is with music. The overriding question remains undetermined, or underdetermined: (Here is a just evaluation of my films, I believe. They supply an affirmative answer to the question, but still the affirmation is underdetermined.) The question is: can motion, of a kind of abstract neoplasticism bear the burden of content in a visual cinema as it most obviously does in the realm of musical experience? The affirmative response to this question is, of course, the premise of my entire career.

I will try to outline my theoretical understanding of this subject in

*Renato Poggioli, *The Theory of the Avant-Garde*, Cambridge, 1968.

the following paragraphs which are still laced with analogies to music which, I am aware, render as much weakness to my argument as strength. There are pitfalls to speculative discussion of this sort which attempts to speak about one art in terms of another. It draws the two together in ways, I am sure, which will one day seem outrageous.

The content that we hear in music proceeds from the temporal architecture of pattern configurations which occupy a spatiotemporal environment whose dimensions are frequency, intensity and density. The key word, architecture, so readily befits the meaning of structure in music that it becomes a facile transfer device to shift one's thinking from the aural to visual. But wait. Do not flip, toggle-wise, from *Cathedrale Engloutir* to Notre Dame de Chartres – from the black key arpeggios of Claude Debussy's little tone poem to the still outlines of a cathedral situated a short distance west of Paris. Instead of transferring the mind from the ethereal fluidity of Debussy (he will have to do since I'm stuck with this metaphor) shift only the shorter distance from Debussy to my misty globules tumbling elegantly in space. In fact, if we could only color those crystal orbs in pastels, then Debussy, and the mists would be a look-alike. But I digress.

If we can hold onto this transfer metaphor, then we must reflect. Reflect that this temporal architecture, these musical configurations start and stop, rise and fall, accelerate and slow to cesura. In the process there is an accumulation and discharge, renewal, gathering and release of tension. Layer upon layer of dynamic forces, all essentially rhythmic, harmonic and periodic, all contribute to subtle, sometimes tremendous, accumulations of tensional energy force.

How can music do this to us? To quote Claude Levi-Strauss: music "...immobilizes the time which is passing.... so that when we listen to it we accede to a sort of immortality."* Is this a clue? Now shift thinking from aural to visual. Is it not possible that I may succeed to hold your attention with fluid visual structures of periodic and rhythmic order to achieve the same accumulative effect? Visually to exercise the same power that the composer has to "immobilize time which is passing?" Here is another quotation: "Music is temporal in the more exact

*Octavio Paz, *Claude Levi-Strauss: An Introduction*, Ithaca, 1970, p. 61.

sense that, for its ends, music enlists time as force." And one more: "Music is temporal art in the special sense that in it time reveals itself to experience."*

Now the power that music holds over us is not so simplistic nor trivial that it can be explained in a few quotations or a few paragraphs or for that matter, even a few books. All in all, I have only touched upon some aspects of the temporal and motion attributes of music and found them paralleling visual properties of my own computer explorations. That is perhaps all that I can do at this time and in this situation.

The question asked a few paragraphs above, of course, can only be resolved in fact when motion within a visual framework does demonstrate that mystical power to extract content from time itself. I can demonstrate that by computer we can manipulate visual motion with a fluidity that rivals those miraculous mists. We can share with music, visually, her own exclusive environment of frequency, intensity and density.○

It can be said about music, in a special sense, that it does not exist at all – it only happens. In just ten years now the visual artist has acquired access to a similar domain wherein visual events can "happen" without prior or subsequent existence. This is, in its own way, Bucky Fuller's knot: "patterned integrity" □ which he ties in thin air. Thus we have at hand an art of spatiotemporal architectonics that lies outside the traditions of the visual arts, or poetry, drama, dance, music – or cinema.

*Victor Zuckerkandl, *Sound and Symbol*, New York, 1956, p.200.
○B. Henisz-Dostert, Rel – *An Information System for a Dynamic Environment*, Pasadena, 1971.
□ Hugh Kenner, *Bucky*, New York, 1973, p. 23.

Democratizing the Audio-Visual Arts 1974

In these program notes for the U.S.A. International Animation Festival, New York, January, 1974, John Whitney introduces the videodisc into his theoretical backpack, hailing it as the particular instrument through which visual music may be perfected and distributed. – *W. M.*

Peter Goldmark contributed to contemporary speculations the intriguing idea that a video-storage home library would serve to decentralize and democratize the U.S. television landscape which is culturally deprived because of commercial obligations to the mass marketplace. Certainly since his remarks, if not before, all home video marketing projections have been conceived as a kind of enterprise resembling book or record publishing. However, your local home video record store at the outset will be stocked with very little to compare in value even with median quality literature or music.

It should be more obvious than it is that a durable art, worthy of that classification, worthy of buying for the home and presumably for viewing over and over, will be in short supply. While it is true that a phonograph album of Beethoven Quartets is not quite a household commonplace, classical records do sell in large numbers. Classical European music and music of other cultures and epochs appeal in such a way as to encourage occasional or frequent replay. It would seem – and this point is most frequently overlooked – that the kind of appeal which encourages replay is the strongest inducement to sell any disk into the home. Music is loved, hence, it sells, because of that appeal. The great wonder of this is repeatability. Music has it. Jokes do not. Few movies do. What TV shows do? Count them on your fingers. There is only an obtuse relationship between "classic" and repeatability. Still the very word

"classic" is a common label for that which has withstood the test of time; i.e. repeatability. The greatest wonder of all is Muzak: the repetition of the familiar gone to seed. **There's** repeatability for you! Match if you can this daily sustenance we derive from music, good or bad, against any other art.

As soon as the record industry came into being, there was at hand and available for the taking, ready-made, an enormous backlog of music – some six or eight centuries worth. And there was a diverse market of tastes for the product. The point is that most extant television or cinema is patently not so designed nor does it merit repetition. Thus, there is scarcely a "backlog" for the videodisc publisher to draw upon, corporate investors optimism on this point notwithstanding.

It is wrong to believe that an industry very well capable of producing such an invention as the new videodisc mechanism is in any way by itself equal to the task of producing a culturally valid, audio-equal-to-visual library which can compare with our global musical inheritance. That musical tradition is quite literally an accrual which derives from generations of extraordinary individual and collective invention.

It would be encouraging to think that an entirely new cultural tradition, an art created fresh for the videodisc, might spring forth in the next ten years. Considering the fantastic interest and random turmoil in student filmmaking and computer graphics and computer music, which I have seen throughout the United States, Japan, and Europe, something like a renascence may be brewing in what appears to be the present so-called underground counter culture. If some sort of renascent culture is in the making, the universities should and will play a role in permitting this to happen. The computer is the most significant instrumentation involved, and at present it is accessible generally only at universities.

Computer technology possesses the most exciting possibilities yet to utilize the fantastic potential of video color phosphores. A point that is frequently overlooked is that the home color video system is potentially the greatest color invention of all time, far surpassing any application of pigments or dyes. What a "bright future" indeed, if we can conceive an art of spatio-temporal architectonics, a color, motion, visual double to music, emerging at this most propitious moment for the videodisc; a videodisc with eye-and-ear-gratifying repeatability.

Industries, especially those which have profited most by a kind of mining (as well as frequent pollution) of our cultural resources, might do well to acknowledge their responsibility to sponsor research directed at creating a new body of knowledge to bring about a fresh color-motion-sound art for the videodisc.

One might observe that university and industry alike have their role to play in the contemporary cultural environment and note, too, it is an environment which is perennially threatened by the Muzaks of commercial pollution. Both institutions may find self-interest served in assuming responsibility toward reordering this condition of modern life no less than reordering the world around physical environment.

There is at present more sponsored research at experimental video-centers around the world. So one must spell out the distinction between video and computer. Computer technology and video have existed as separate hardware domains, but as raster-scan techniques are being applied more and more to computer displays, the fields are merging. Nevertheless, the fundamental design problem of a new visual double to music is to deal with graphic structure on a **deep level** as with the patterned structure of music. Video techniques cannot cope with these problems; only computer software does. Video synthesizers fail at the point where the computer-generated image begins; where pattern is the true product of deep structure, not a mere video analog frequency permutation.

There is a great need for exploratory study of motion-design structure at the **computer** level, a need to reset priorities which are at present inverted. Video control of transformations and color is already being explored and will provide orchestration in the form of color and textural enrichment to basic design when it flows innately from deep structure.

To summarize: the videodisc is the most likely among the contenders for the home aural-visual record library. Aside from its value as a reference source, this library will be stocked with a world of pleasures that will command our responses again and again – else who needs a library? Today, music is our only model for this kind of enjoyment. Examine in depth the properties of music; then an alert observer in these times will discover that audio and visual outputs of the computer are the key to that garden of future delights.

Computational Periodics 1975

John Whitney coined the term "computational periodics" in response to a questionnaire Ruth Leavitt circulated in preparing her anthology *Artist and Computer*. He felt it was too pompous or unwieldy right from the start, but it was the best name available at that time. The crisp statement is still interesting to see the alternate versions and steps one takes on the way to a better solution. – *W. M.*

We may assume that a time will come when that which I am about to describe will name itself, but for now: 'computational periodics' is a propositional and tentative term which may help to designate a new unified field for a heterodimensional art, a field whose special dimension is time, and thus an art that is temporal like music, but further, spatio-temporal, an art whose time has come because of computer technology and an art which could not exist before the computer. Even though this art will be found in the notebooks of Leonardo and has been in the collective imagination, like the flying machine, since his epoch it was a technological impossibility until the development of computer graphics.

Rhythm, meter, frequency, tonality and intensity are the periodic parameters of music. There is a similar group of parameters that set forth a picture domain as valid and fertile as the counterpoised domain of sound. This visual domain is defined by parameters which are also periodic. 'Computational periodics' then is a new term which is needed to identify and distinguish this multidimensional art for eye and ear that resides exclusively within computer technology. For notwithstanding man's historic efforts to bridge the two worlds of music and art through dance and theatre, the computer is his first instrument that can integrate and manipulate image and sound in a way that is as valid for visual, as it is for aural, perception.

That rare talent of the composer to create music which is self sustaining, i.e., the power of music to capture and hold our attention, is a sophisticated and subtle art which has been the exclusive gift of only a few composers in each of many past generations. It was a pedagogic skill, however, that a pupil might learn, provided he was himself possessed with latent genius. In this century all that pedagogy has been reduced to anxious uncertainty. The harmonic and metric traditions, for one thing, seem to be untranslatable into the new periodic resources that abound in computer technology. The body of knowledge that resulted, by the nineteenth century, in musical works of ponderous scale and proportion, is a lost art. By the standards of the Baroque era the present has retrogressed to infantilism.

The new composer, and the visual artist who may aspire to deal with teleonomic structures, could as well be the child of some early dark age. The Twentieth Century began with technology and has reaped a whirlwind of cultural dislocations and amnesia. Materials and forms and attitudes are so altered that past traditions are generally moribund.

Also from the point of view that this Century is but an episode in the life of human culture, it is clear that more paraphernalia of this epoch may be cast off than will survive into the next. Yet surely the computer will not. A solid state image storage system will replace the silver chemical ribbon and cinema will eventually be interred in the archival museum. But computer and computer graphics bring to mind the kind of tools that may characterize an age succeeding this century's age of the machine.

The computer is the coequal of the entire repertoire of musical instrumentation and heir to that domain of musical sound. At the same time, the computer is the ultimate kinetic image generative instrument. The kinetic image is in truth the creation of computer graphics since the cine or television is but a recording device and the hand-drawn image of motion is but a cartoon of motion.

Tatlin, Rodchenko, Gabo, Moholy-Nagy, Fontana, Duchamp, Kandinsky, Mondrian, Pollock and twice that many more artists of this century testify to the drive toward dynamic organization of energy and force in art, and toward ephemeralization of the art object in painting and sculpture. The past decade has seen that direction lead many artists to cinema, exotic technology and experiments with cybernetics. Yet it has

passed generally unnoticed that this preoccupation of the last one hundred years has been toward a **musicalization** of visual art. For the urge to produce abstract architectonic structures that possess fluid transformability in visual space is no less than a grand aspiration toward music's double in the visible world. It is as a preoccupation with art in this exclusive sense that we may use the term computational periodics.

Appendix

Digital Pyrotechnics 1977

This, the final form of an article that had appeared in *Interface* and *Beyond Baroque* magazines, was delivered at the First Computer Faire and published in their proceedings, 1977. Here John Whitney formulates and illustrates his full-blown theory of visual harmonies. – *W. M.*

Abstract:
Harmonic forces give shape to our experience of past and future. This is the dramatic essence of musical experience. It is why the composer, more or less intuitively, has manipulated the network of harmonic relationships of all musical scales for as long as music itself has existed. Evidence is accumulating to substantiate the need for much further study of harmonic phenomena. Because there is reason to believe – as I do – that the tensional charge and discharge – the expectations evoked and thence fulfilled by tonic structures in music – is a direct product of the mathematics of harmonic order. I further believe that the same possibilities exist in the skillful design of harmonic pattern for visual perception. Therefore, I am exploring harmonics designed for eye instead of ear. It is interesting to note that the very creation of harmonic pattern had been altogether inconceivable until a very recent time when computer graphics eventually and slowly became available to the visual artist.

I'd like to show how well computer graphics and harmonic pattern are suited for each other. And show how useful this compatibility can be for employing the computer to charm the eye.

To begin, let's consider that manner by which composers for centuries have used harmonic "force" to attract and hold the attention and otherwise charm the ear. Then we will examine a similar form of visual "force" which has been made possible by computer graphics.

At the outset we know the musician's aural spectrum to be an undifferentiated and continuous spread of frequencies, say from twenty to twenty thousand cycles. Yet this apparently homogeneous continuum is not continuous at all. Harmonic relationships interactively transfigure this spectrum. Harmonic phenomena create discontinuities, as nodules of tension, anticipation, and resolution deform this otherwise smooth continuum. Whole number, or harmonic nodes, scattered throughout the

spectrum create order/disorder proclivities: centers of emotional focus which distort an otherwise smoothly ascending texture. In fact, sounding tones over the span of just one octave persuades the ear that we are nearer a return back to the start than we are advanced along any straight line of upward continuous ascension.

I want to suggest that it is this particular discontinuity, not really any other quality of the audio spectrum, that constitutes the raw material of the composer's art. Not pitch, texture, rhythm, and meter. Not frequency, intensity, and density, as most 20th-century modernists have us believe.

That is to say, no matter how we divide the spectrum into steps we find a hierarchy of perceptual values that distinctly rank each step. It is the composer's cunning, or intuition, or even mindless exploitation of this hierarchy that is the primary source of rhythmic vitality and emotional content of music. The composer, however, must cooperate with these natural harmonic forces, or see his strategies defused by them. He cannot work his will against, nor exercise insensitivity to the charge and discharge. He cannot escape the dominion of the gravitational force of harmonic moment.

Furthermore, as a corollary to all the above, a visual domain of harmonic consequence has become accessible through computer graphics. With the graphical display rooted upon coordinate mathematics it is only natural that a great variety of periodic interference patterns can be produced. The motive now exists for the artist composer to discover his way into this diverse domain of dynamic visual form structured out of two-and three-dimensional harmonic periodicity. This domain abounds with tonic centers of focus as in music. And this domain will render up an equivalent rhythmic and emotional content as in music. I think we will soon see the artist learn to cooperate anew with natural harmonic forces in hitherto unexplored visual territory.

In truth, harmonic forces give shape to past and future. Yet harmonic force is not all that mysterious. We can speculate why the sound of "ti" urges us on to "do." Significantly a good diagram for the perceptual dynamics is found. (See pp. 70–71 and the flipbook.)

It is characteristic of harmonic phenomena, visual, aural, or otherwise, to show this kind of pattern. As patterns go, the illustration is perhaps explicit in a way that is even more obvious than the aural, leading-tone

effect of "ti" upon "do."

Eye and ear, each in its own unique manner, experiences the dynamics of this kind of pattern as an event in time – as punctuation. Especially as an event of arrival or departure. When we arrive at "do," the octave above the tonic "do," we hear that rudimentary relationship with a particular infallibility. If we sample ascending steps of the scale, the ear is bound to sense the final event of arrival just as the eye can see arrival and departure relationships in the illustration. I might add that these relationships are many times more explicit when seen as a motion picture sequence.

In terms of visual perception, vaguely a corollary to aural responses, we have here a phenomena of hierarchical distribution and classification of elements into an array in which all are ranked according to some perceptual scale of complexity.

No need to argue which pattern is more "consonant" than another, for generating dynamic patterns here is an order/disorder principle, or a consonant/dissonant principle, to work with. It is a principle which can be exploited in more ways than one might expect to give meaningful order to temporal development. The principle becomes a composer's valid strategy – probably the first strategy to be so defined and applied in the brief history of the art of the computer graphics.

Finally, it is worth remarking that the illustration for this article could not be created by a conventional hand-drawing technique – at least that would be quite difficult. Moreover, it would be impossible to hand-animate the film from which the illustration was derived. Many of these films required thousands of drawings while the computation for plotting is staggering. Thus the computer is the ultimate and the only tool for visualizing the dynamic world of harmonic functions. This may serve to illustrate the point that this new world of visual art cannot be confused with any previous traditional forms. (See *Art International,* Vol. XV/7, September 20, 1971, or reprint on pp. 190–97, appendix.)

It should be of particular interest to realize that computer graphics, this 15-year-old infant, is patently capable of bringing forth a totally different kind of visual experience as unique and riotously enjoyable as the Chinese, pre-Christian invention of fireworks.

Film Music 1977

Roy Prendergast's interview with John Whitney for his book *Film Music* juxtaposes the improvisational style of the early oil-wipe films with the issue of control and balance in the mature computer film *Permutations*. Thus he brings us ideologically full circle: the intuitive, handmade film depending on "inspiration" is replaced by a conscious, instrumented film depending on sensitive, disciplined manipulation of natural harmonic laws. – *W. M.*

Work with animated sound has not been carried significantly further (if that is indeed possible) in recent years and one finds filmmakers like John Whitney going back to traditional music or onward into computer technology. Whitney's film *Matrix,* for instance, uses some of the piano music of Antonio Soler. Whitney has, however, carried forward his concepts concerning similarities between the visual and aural arts. "At the outset the similarities obtain only a visual world that is completely dynamic," he emphasizes.

During the late 1940s Whitney was awarded a Guggenheim Fellowship for two years. "During that time, [I] developed some spontaneous real-time animation techniques. I could manipulate paper cutouts to music. I was working with jazz – music that had no pretentions and none of the complexity and subtlety of structure of traditional Western art music. I was finding ways to satisfy my own concepts regarding the dynamics of visual motion by ways that avoided the tedium, stasis, and the restrictions that you have with any cell animation or any conventional techniques. I was manipulating cutouts and working with fluids, very much as they were later to be used in the light shows. I had an oil bath on a level tray with the light below. I put dye into the oil until it was deep red, and then used red-blind film in the camera. With my finger or with a stylus, I could draw on this thin surface of oil; drawing

would push the oil away and the light would shine through so I could draw calligraphic, linear sequences very freely; and by selecting the weight and thickness of the oil, I could control the rate at which the line would erase itself, so that it was constantly erasing with a constantly fresh surface to draw on — the ultimate tabula rasa. I was doing that and manipulating paper cutouts, and then doing a lot of direct etching on film as McLaren had done. I made, during that time, half a dozen little films to classic jazz recordings such as Will Bradley's.

"At that time I was building much of my own equipment including a selsyn interlock system. The sound track was previously recorded, and it could be run backward and forward in interlock with the camera. The only cue I had as to my progress in making a film was what I could hear along the soundtrack; so I would rehearse two or three riffs of a piece, plan it more or less spontaneously right there and then shoot it; then back the film up to work another section or over the same section, or make a superimposure over that. Accumulatively, I was painting a complex moving image on film. I'd shoot complete three-minute films in one afternoon's work."

The important thing about Whitney's work in this area was that it pointed to a kind of spontaneous performance – much like improvisation in music. Whitney points out that this system "pointed to something else: to give up film techniques entirely and begin to explore video techniques. I made a proposal in the early fifties at UCLA that we set up an arrangement with six or eight video cameras and six or eight performers using these various manipulation techniques – the cameras were to be mixed electronically – then we'd perform a real-time graphic experience as an ensemble. The very idea of an ensemble to 'perform' a visual art is quite valid. I think and hope it will happen some day."

In a film entitled *Permutations,* Whitney has consciously carried the consonance-dissonance (relaxation-tension) concept of music into the visual arts through the imaginative use of computers. Speaking of the dots that create the graphics of the film, Whitney points up the similarities of the effect, created by the graphic figures, to some of the tensional effects created by music. Whitney says: "Every one of the points in *Permutations* is moving at a different rate and moving in an independent direction in accord with natural laws as valid as Pythagoras's

while moving within their circular field. Their action produces a phenomenon which is more or less equivalent to musical harmonics. When the dots reach certain numerical (harmonic) relationships with other parameters in the equation, they form elementary many-lobed figures. Then they go off into a nonsimple numerical relationship and appear to be random again. I think of this as an order-disorder phenomenon that suggests the harmony-dissonance effect of music. Graphically, as a static illustration in a book, it may not be as striking as it is to perceive the dynamics of the experience on film."

Whitney does, however, see the inherent fallacy of trying to invent a technology that would produce a musical counterpart to graphics or vice versa. For him, "music is sort of a narrow road I'd like to try to steer my own way through. I don't want to go in either of two directions. For example, I don't want to be mechanistic about art. And yet I'd like to begin to work with parallels which abound within the computer system for sound and image. Let me add, I am not composing music right now simply because I have my hands full with what I'm doing about the graphic formal problems."

Whitney rightly observes that creating some sort of musical score that would simultaneously generate a graphic countervoice would be "just as arbitrary to do as to invent a machine whereby I might compose the piano part while the machine does the violin part of a duo musical work. Yet all in all the great music of the future may well be heterosensuous."

In his more recent films Whitney has been trying to achieve the same kind of control that the composer has with music. I see the composer as an intuitive architect creating and manipulating aural material which has the effect of producing distinct feeling states on the listener. However, Whitney "agrees with Stravinsky that the problem of music is essentially one of architecture. A kind of spatial architecture. The emotional response is solely a by-product or a natural, inevitable development from that."

Whitney draws this concept into his film work, believing that "it is possible to create a spatial architecture that the eye can perceive and that has the same kind of potential for emotive consequences as the most profound music."

Whitney also feels that he is gaining more and more control over the effects he wishes to create. He says: "I do have a cautious, unfolding confidence in being able to predict effects that I know will affect you. But one technical development that is urgently necessary is production in real time. I think as soon as we have computer graphic systems that produce the kind of fluidity I'm presently able to generate, being generated in real time, then we're going to be able to achieve something fantastic.... Then we're going to really begin to make exciting film experiences. And I'm sure these developments will have revolutionary consequences for the composer and musical audiences though all this may be inconceivable to us right now. For example, we do not even clearly understand the relationships between the spontaneous and the cautious, the contemplative and the planned in musical art."

Whitney sees another relationship between the graphic structure of his film *Permutations* and musical structure: "Notice that in music, frequently the first hearing of a piece of music is not transparent to you. In fact, with better music, often enough (it is a truism), if you're not totally familiar with the composer, the sections that you'll like most in the long run will be those which are hardest for you to appreciate upon the first hearing. I would argue that, with my recent films there is this quality: if you see a film again and again you will discover more structure. It will become more revealed to you that the whole work is a structure possessing its own kind of pattern integrity. It is unfortunate that our film viewing conventions do not permit the repetition we allow with music."

As advanced and sophisticated as Whitney's theories and films are, he clearly perceives that his art is, in many ways, still in an embryonic stage. He asks: "What if eight tones of the musical scale hadn't been discovered yet? What if our composers had only four tones to work with? And... what if the pianist had to wait twelve hours before he could hear the keys he had played? And, on the other hand, what if we could buy and play in our home these new visual compositions as freely as we play music recordings? Probably we will soon. And I expect we'll soon find the missing notes."

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John Whitney Filmography

Untitled film of lunar eclipse (1939), 5 min., color, silent [8mm].

Twenty-Four Variations (with brother James Whitney, 1939–40), 5 min., color, silent, [8mm].

Three untitled films (with brother James Whitney, 1940–42), 5 min. each, color, silent, [8mm].

Film Exercise #1 (with James Whitney, 1943), 5 min., color, sound: synthesized pendulum music.

Film Exercises #2 and *#3* (with James Whitney, 1944), 4 min., color, sound: synthesized pendulum music.

Film Exercise #4 (with James Whitney, 1944), 7 min., color, sound: synthesized pendulum music.

Film Exercise #5 (with James Whitney, 1944), 5 min., color, sound: synthesized pendulum music.

Celery Stalks at Midnight (oil-wipe technique, ca. 1952), 3 min., color, sound: Will Bradley.

Hot House (oil-wipe technique, ca. 1952), 3 min., color, sound: Dizzy Gillespie.

Mozart Rondo (oil-wipe technique, ca. 1952), 3 min. color, sound: Mozart's "Rondo a la Turca."

Old Macdonald Had a Farm (oil-wipe technique, ca. 1952), 3 min., color, sound: children's song.

Chimes Blues (oil-wipe technique, ca. 1952), 3 min., black-and-white, sound: Turk Murphy.

Third Man Theme (oil-wipe technique, ca. 1952), 3 min., black-and-white, zither sound. Anton Karas.

Down Home Rag (oil-wipe technique, ca. 1952), 3 min., black-and-white, sound: Red Nichols.

Egyptian Fantasy (oil-wipe technique, ca. 1952), 3 min., black-and-white, sound: Sidney Bechet.

I Want to Linger (oil-wipe technique, ca. 1952), 3 min., black-and-white, Pete Daily.

Drums West (oil-wipe technique, ca. 1952), 3 min., black-and-white, sound: Shelley Manne.

Lion Hunt (produced at U.P.A. studios, 1955), 3 min., color, sound, [35mm].

Blues Pattern (produced at U.P.A. studios, 1955), 3 min., color, sound, [35mm].

Performing Painter (produced at U.P.A. studios, 1955), 3 min., color, sound, [35mm].

Catalog (collection of computer-graphic effects, 1961), 7 min., color, sound: Ornette Coleman.

Hommage to Rameau (computer graphic, 1967), 3 min., color, sound: Rameau's "La Timide" and "Premier Tambourin" from *Pieces De Clavecin En Concerts*.

Permutations (computer graphic, 1968), 8 min., color, sound: Indian tabla music by Balachandra on 16mm prints.

Experiments in Motion Graphics (prepared as a silent film to accompany lecture at Aspen, 1967; narration added 1968), 13 min., color, sound.

Osaka 1-2-3 (computer graphic, 1970) 3 min., black-and-white, sound: kabuki music.

Matrix I (computer graphic, 1971) 6 min., color, sound: Antonio Soler sonatas arranged and performed on piano by Delores Stevens.

Matrix II (same computer graphic visuals as *Matrix I*, 1971) 6 min., color, sound: music from Terry Riley's *Rainbow in Curved Air*.

Matrix III (computer graphic, 1972) 11 min., color, sound: music from Terry Riley's Rainbow In Curved Air.

Hex Demo (computer graphic, 1973) 3 min., black-and-white, silent to accompany lectures, demonstrating digital harmony.

Arabesque (computer graphic, 1975) 7 min., color, sound: Manoocheher Sadeghi.

Permutations II (computer graphic footage of *Permutations* re-edited, 1979) 7 min., color, sound: original score composed by William Kraft. This version available on videodisc or videotape.

The 16mm films listed above are available in 16mm prints and videotapes from Pyramid Films, Box 1048, Santa Monica, California 90406, (213) 390-3456. A videodisc containing three films by John Whitney *(Permutations II, Matrix I, and Arabesque)* is available from MCA Discovision, 100 Universal City Plaza, Universal City, California 91608, (213) 985-4321.

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